POTENTIAL RECHARGE ESTIMATES OF ARCTIC LAKES TO AID WATER MANAGEMENT ON THE NORTH SLOPE OF ALASKA

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A

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Abstract

Water is a valuable asset to the petroleum industry on the North Slope of Alaska. Current water-permitting processes do not take into account watershed principles in the allocation of water resources. This has primarily been due to lack of information related to tundra lake watersheds and associated water use. This thesis evaluated several study lakes located within the eastern portion of the National Petroleum Reserve Alaska (NPRA) to demonstrate how watershed and meteorological parameters could be incorporated into water-use management practices. Watershed areas were delineated for the study lakes digitally with geographic information systems (GIS) and Rivertools software. Estimates for rainfall, snow-water equivalent, and evapotranspiration were combined to calculate potential recharge estimates for each individual study lake. A potential recharge tool was developed to help calculate potential recharge values. This tool can be a good first step for industry to begin to apply watershed principles into the water-permitting processes.

For the study lakes analyzed, it was concluded that water withdrawal would not adversely affect the sustainability of the water bodies. With the current level of available data, recharge estimates are accurate enough to be used in permitting processes. It is recommended that geographic lake parameters (i.e., watershed and lake areas) and meteorological parameters (e.g., rain, snow, evapotranspiration) are further studied and included in future lake permits.

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Introduction

The petroleum industry on the North Slope of Alaska requires large quantities of water for production and exploration activities. Water is necessary for drilling, enhanced oil recovery, camp operations, and ice roads and pads. Since permafrost underlies the region, groundwater is not a significant source of freshwater; local tundra lakes and engineered reservoirs provide the largest source of useable water for the oil companies.

Ice road construction is one of the largest water users. The construction of ice roads allows exploration to occur with fewer harmful environmental impacts than gravel roads. The construction of these roads typically begins in December or January when the Alaska Department of Natural Resources (ADNR) determines that the tundra is adequately frozen and covered with adequate snow to support tundra travel. Commonly, water from nearby lakes is sprayed on top of packed snow to create an icy layer. This process is repeated until the road is thick enough to support vehicle and large drilling-rig traffic. Ice may also be chipped from the lakes' surfaces and used in ice road construction. These ice chips speed up the road building process, while also making the roads sturdier. Ice chips are typically removed from areas of the lake where the water has frozen to the lake bed.

The speed in construction for ice roads is critical since the lifetime of the road is dependent upon seasonally changing temperatures. The planning of ice roads becomes critical so that the road can be used for the maximum amount of time. Only lakes that have been permitted by ADNR can be used for ice road construction. Lake identification and permitting can make the construction process challenging as numerous lakes must be pumped for the construction of a single ice road.

The lake permitting process has generally been controlled by the presence, or potential presence of aquatic life. Pumping large quantities of water from lakes could potentially impact fish species if the habit is altered. Typically, but not exclusively, the allowable volume for withdrawal is limited to either 15 or 30 percent of the under-ice lake volume: 30 percent of under-ice volume is allowed if there are no known fish species sensitive to low concentrations of dissolved oxygen (DO), while only 15 percent is allowed if there are known sensitive fish species.

Water withdrawal can potentially affect fish species in two distinct ways: physically and chemically. Physically, the sustainability of these lakes can be threatened if water is not adequately replaced through recharge. If a lake does not fully recharge each year, it may drain over time affecting the fish habit. Chemically, such parameters as dissolved oxygen may be affected by pumping (Hinzman et al., 2006).

This thesis analyzes the physical parameters influencing lake recharge dynamics. Lake watershed areas and meteorological parameters were studied to gain a better understanding of the hydrologic processes in the region. A tool was developed to help better manage the use of water and aid in demonstrating need for applying hydrologic principles to current water use practices. Since the current approach does not incorporate hydrology, it will be important to make the tool practical for a wide range of users.

Background

Research for this thesis is part of a larger study known as The North Slope Lakes project. The North Slope Lakes project was initiated to study the effects of winter water use on tundra lakes. Phase 2 of the project was finished in 2008. Phase 1 was completed in 2005. Phase 1 primarily looked at water use for ice road and ice pad construction and the environmental consequences that may come with such water use.

From September 2002 to August 2005, selected study lakes were analyzed to determine the effects of mid-winter pumping. The initial four study lakes were located in the Kuparuk operations area. Two of the lakes (K113C and K203C) were unpumped control lakes, while the other two lakes (K209P and K214P) were pumped. In 2004, two additional lakes were added to the study from the Alpine operations area (L9312 and L9817). Lake L9312 supplies fresh water to the base camp at Alpine, while Lake L9817 is periodically used for ice road construction. Lake L9817 is located approximately 20 km west of the Alpine operating area and not accessible by a year-round road. Therefore, less frequent observations were possible at this study lake. For the years of 2003, 2004, and 2005, visual observations showed complete recharge during the snowmelt periods at all of the Kuparuk study lakes. Lake L9312 was completely recharged in both 2004 and 2005, however from different processes (Figure 1). In 2004, the lake was recharged from the Colville River overflowing during snowmelt. In 2005, the Colville did not flood the lake watershed, yet full recharge was observed in the summer months from snowmelt and rainfall. At Lake L9817, recharge observations were not available in 2004. In September

2005, the lake had visible overflow indicating that the lake had fully recharged prior to freeze-up.

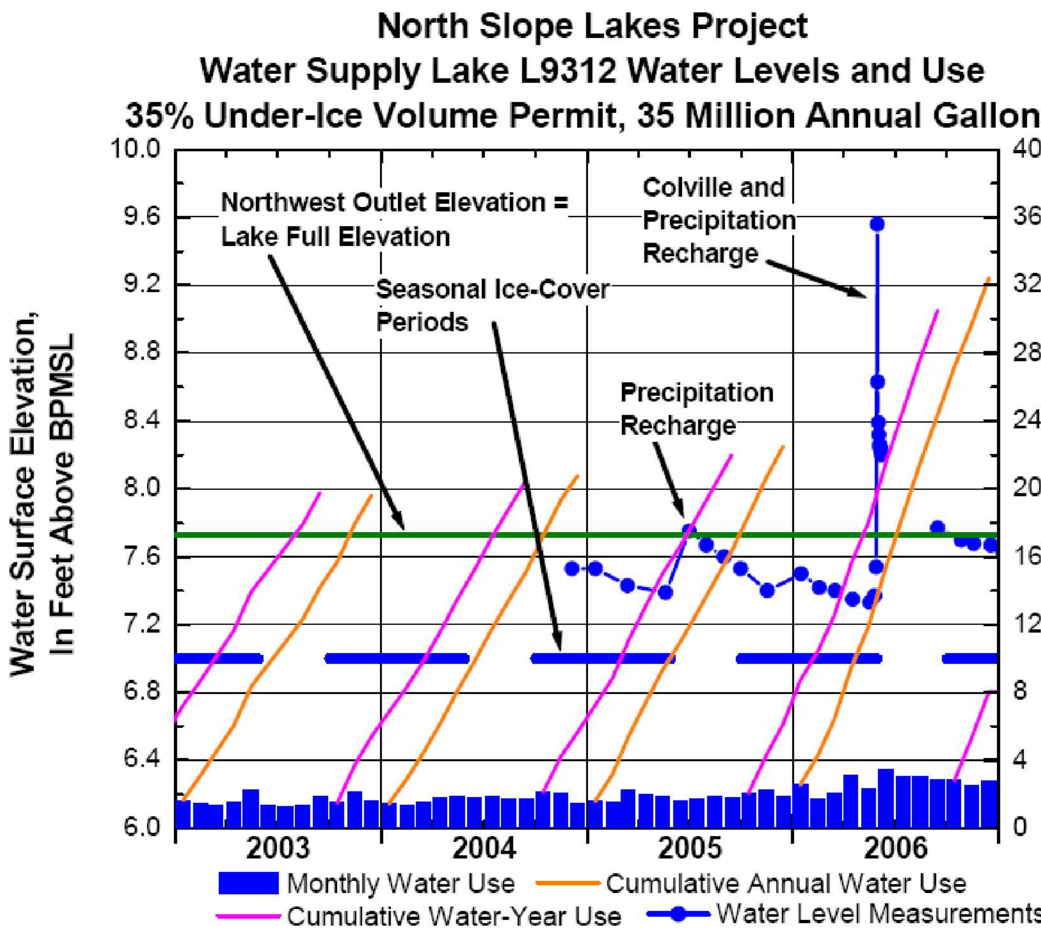


Figure 1 - Lake L9312 water levels and water use (Lilly and Reichardt, 2007).

Phase 1 concluded that there were no measurable negative impacts of winter pumping on the lakes studied. Water use practices were found to be conservative. However, there was room for improvement. The water-year (October to September) was recommended as being a better management period of analysis since it better represents the hydrologic cycle in the region. Further, it was recommended that ice chips removed from grounded ice regions of a lake not be included in the volume of water permitted for extraction. Finally, it was recommended that a better understanding of hydrology and water use on the North Slope would benefit industry, management agencies, and protection of the environment (Hinzman et al., 2006).

Phase 2 of the North Slope Lakes Project started in 2005 and was completed in 2008. One of the objectives of Phase 2 was to expand the hydrologic data collection network. Several study lakes were added to the project, and were monitored during monthly winter field trips. A network of weather stations was also installed in the oil fields and NPRA. Another objective was to provide operational modeling tools to improve estimates of water availability. This thesis work created such a tool. The tool addresses both winter and annual water use. Phase 2 was also formed to create a model to improve the understanding of chemical changes in arctic lakes to support water use. This was accomplished with the development of an under ice DO model.

Literature Review

It is not reasonable to perform this study without a detailed understanding of the Alaskan Arctic Coastal Plain, the regional meteorology, and general arctic hydrology. Many differing factors influence water dynamics of the arctic environment and can make research and analysis difficult.

Alaskan Arctic Coastal Plain

The Alaskan Arctic Coastal Plain is a low relief, treeless region covering approximately 70,900 km^2 (Walker, 1973). The area lies between the Arctic Ocean to the north and the Brooks Range foothills to the south. Common landforms include polygons, strangmoor ridges, and pingos (Everett and Parkinson, 1977). Vegetation in the region consists of Carex and Eriophorum sedges, mosses, prostrate willow shrubs, and various flowing herbaccous plants (Rovansek et al., 1996). Soils are high in organics of approximately 8,000 – 10,000 years in age (Jorgenson et al., 2002). When moving in towards the Arctic Ocean from the Brooks Range foothills, eolian sands and marine alluvium soils are common. The main surface soils in the region are late Quaternary unconsolidated sands and gravels (Black, 1964). Groundwater is not common in the area due to the permafrost that extends from near the surface to more than 500 m (Osterkamp et al., 1985). In rare cases, unfrozen hydraulic channels can exist (Hinzman et al., 2006).

The Alaskan Arctic Coastal Plain is dominated with surface water, with an estimated 50 – 75% being covered by lakes, ponds, or old thaw lake basins (Hussey and Michelson, 1966). Due to the presence of continuous permafrost, groundwater infiltration rates are very slow causing much of the land to be saturated. Wetlands make up an estimated 83% of the Alaskan Arctic Coastal Plain (Hall et al., 1994). Due to high evaporation rates, this percentage of wetlands decreases as the summer progresses (Bowling et al., 2003). Lakes are more common near the coast, but most of these bodies of water are less than 2 meters deep. Moving inland, the amount of lakes decreases, while the average lake depth increases (Truett and Johnson, 2000). One study was conducted using remote sensing to determine lake depths near Barrow (Jeffries et. al., 1996). The study showed that 23% of lakes are more than 2.2 m deep, 10% are between 1.5 m and 2.2 m deep, 60% of lakes are between 1.4 and 1.5 m deep, and 7% are less than 1.4 m deep. The geomorphology of the lakes on the Alaskan coast is relatively similar. Most lakes are elliptical with a long northwest-southeast axis, perhaps driven by prevailing winds in the similar direction (Carson and Hussey, 1962).

Several classifications of arctic lakes have been developed in past studies (Hablett, 1979; Bendock and Burr, 1985; Moulton 1998). These classifications are generally based on the lake's aquatic habitat potential, yet rely on hydrologic dynamics as well. The most commonly used system of classification in the NPRA region is based on Moulton (1998), that defines lakes based primarily on the potential for access by fish in the Colville Delta:

- Perched (Frequent Flooding) = A lake with an obvious high water channel, likely subject to annual flooding;
- Perched (Infrequent Flooding) = A lake with no obvious high water channel, likely subject to flooding on an infrequent basis;

- Drainage = A lake that is part of a defined drainage system, i.e. there is an active connection to a creek;
- Tapped = A lake with an active connection to a river channel during the summer. The channel is normally a short, low velocity channel formed when the lake was tapped and drained;
- Tundra = A thaw lake not within or connected to the Colville Delta, little potential for fish access on a regular basis.

In his study of 176 lakes, he found that 25 were perched lakes (frequent flooding), 83 were perched lakes (infrequent flooding), 22 were drainage lakes, 15 were tapped lakes, and 31 were tundra lakes. The two primary lakes considered in this study were perched and tundra lakes.

Regional Meteorology

Understanding the regional trends and spatial distribution of parameters such as temperature, rainfall, snowfall, evaporation, and wind speed are fundamental to this hydrologic study. Unfortunately there are very few meteorological stations on the North Slope of Alaska, and even fewer that have been reporting long term (>20years). The accuracy of the stations is also suspect. Due to high winds, precipitation events (especially snowfall) are often underestimated. Actual values have been found to be two to three times greater then what has been reported by the National Weather Service (Yang et al., 1998). Coupled with this is the potential of a warming climate and changing temperatures. These issues have created a scarcity of reliable data in the region, though the development and growth of the petroleum industry has brought along increased research and data collection.

The average annual air temperature at Prudhoe Bay is -11.4 C. Temperatures are generally under 0 C from mid September to mid May. Summers usually last from early June to early September. Average temperatures during the summer months range from 3 C to 11 C.

Precipitation in the region is generally low. An 11 year average from Betty Pingo shows an average annual precipitation (rain and snow) of 23.0 cm. Approximately 50% of the annual precipitation in the region falls as snow (Robinson, 1995). Figure 2 shows the cumulative rainfall totals for the Fish Creek weather station from 2003 – 2007. The summer of 2007 was the driest year on record for most of the reporting stations on the North Slope. Rainfall normally occurs during late July and August, with June usually being dry due to the ice cover of the Arctic Ocean (Hinzman et al., 2006). Strong winds are common in the area, reaching up to 16 m/s at times. Winds usually blow in from the northeast (Hinzman et al., 2006).

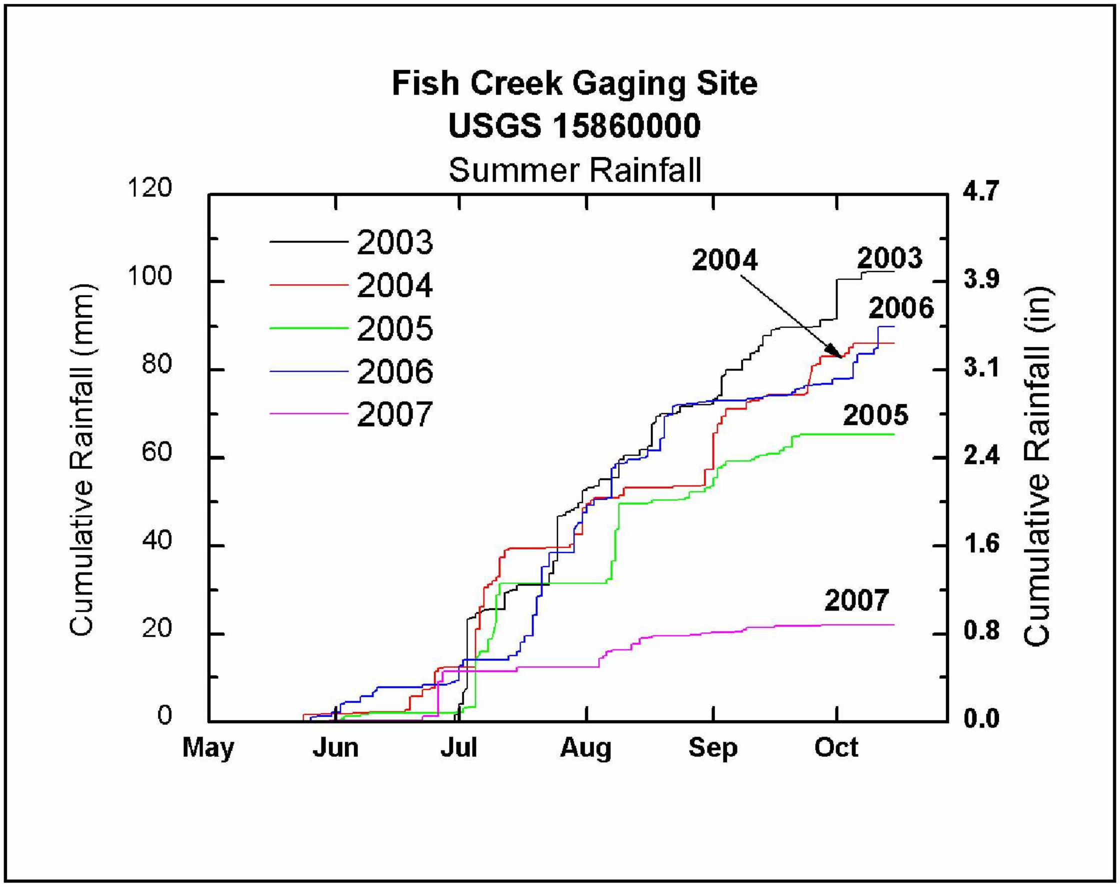


Figure 2 - Cumulative rainfall at Fish Creek weather station from 2003 - 2007.

Lake evaporation and evapotranspiration (ET) are the main sources of outflows for the summer months. Several studies have been conducted on evaporation rates on the Alaskan Arctic Coastal Plain (Kane et. al., 1990; Mendez et. al., 1998; Rovansek et. al., 1996). Lake evaporation is generally higher than tundra evapotranspiration in these wetlands regions (Mendez et. al., 1998). ET peaks during mid June and decreases as the summer progresses. Various methods have been studied and researched, and it has been found that the Priestly-Taylor method can accurately predict ET with the least amount of required inputs (Mendez et. al., 1998).

Arctic Hydrology

Limited research has been conducted on the hydrology of the Alaskan Arctic Coastal Plain. A large part of the research has been driven by oil exploration and development in the area. As this development continues, it will be increasingly important to better understand the region's hydrologic dynamics. Conversely, several factors make hydrologic studies difficult. Rovansek et al., 1996 recognized three underlying reasons for the limited research:

1. the remote location and extreme climate makes research difficult;
2. it is difficult to assess the contribution of overland runoff to the water balance due to the difficulty in delineated watershed boundaries;
3. subtle topography allows overland flow directions to change seasonally and as dictated by snow damming.

Permafrost strongly influences the hydrology on the North Slope of Alaska and is defined as soil that has been continuously frozen for two or more years (Davis, 2001). When the water freezes, it basically plugs up voids within the soil. The frozen water results in a very large decrease in the hydraulic conductivity of the soils (Kane and Stein, 1983). The assumption of impermeability is often made because of the exceptionally low hydraulic conductivity. The permafrost acts as a confining layer minimizing surface water infiltration and increasing surface water storage. This creates wetlands in an area that receives little annual precipitation.

The water balance method is a common approach used to conduct hydrologic studies. Detailed and complete water balances have rarely been done in northern wetlands regions (Kane and Hinzman, 1988; Ford and Bedford, 1987). However, there have been several studies done that incorporate simple water balance approaches in arctic regions (Kane et al., 1990, Lafleur, 1990). For most of the water balance methods, an unknown term is calculated as the sum of the other known water balance components (Glen and Woo, 1997). This can create a problem, in that the error from the associated terms carries over to the unknown term.

Subsurface flow in this region is often neglected in hydrologic studies due to extremely low hydraulic conductivities (Rovansek et al., 1996; Glen and Woo, 1997; Rouse, 1998). Subsurface flow between bodies of water is rare, and often not seen in the arctic environment of continuous permafrost (Rovansek et al., 1996).

Methods

<u>Study Site Lakes</u>

The location for this study is the North Slope of Alaska. The North Slope Lakes Project has studied lakes in both the BP and Conoco Phillips oil fields. This thesis primarily focuses on selected study lakes within the National Petroleum Reserve Alaska (NPRA), while general hydrologic observations and meteorological trends will be applied from all North Slope Study lakes during analysis. Figure 3 shows the North Slope of Alaska, with the study area for this thesis outlined in a black box.

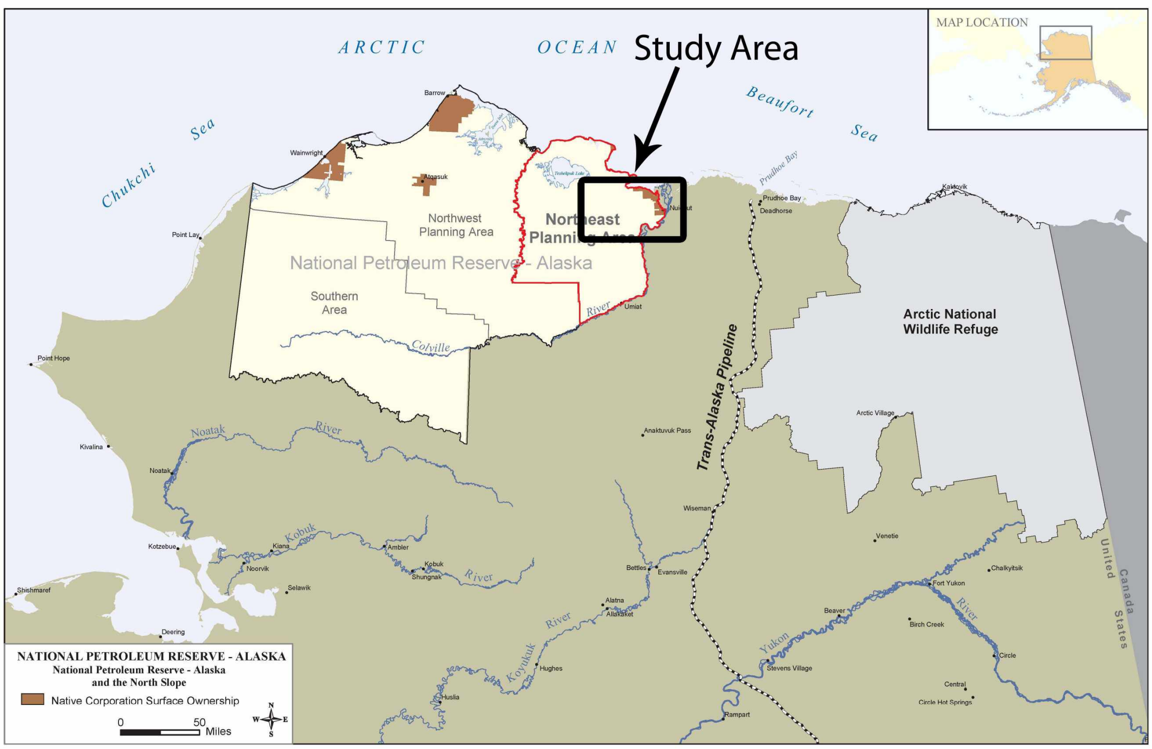


Figure 3 – National Petroleum Reserve Alaska and the North Slope (modified after USDOI BLM and MMS, 2003).

All study lakes are located in the Arctic Coastal Plain with most residing 15 - 30 km south of the Arctic Ocean. The region is relatively flat with increasing changes in relief when moving westward. This increased relief creates more defined drainage patterns in the west end of the study area. Lake connectivity is more common here, while isolated perched lakes are more common in the east. The Colville River flows just east of the study site, and periodically floods Lake L9312, the eastern most study lake. All of the lakes were created through thermokarsting processes (Hinzman et al., 2006). Shallow ponds are common in the area, often less than 1 meter deep. Most of the study lakes are deeper (>2 meters), with lake depth increasing southward from the coastline. All of the selected study lakes have previously been pumped or harvested for winter ice road construction. The Digital Elevation Model (DEM, described in *Watershed Delineation* section) covers all the study lake regions, allowing for digital watershed delineation to be possible.

Lakes were categorized based on the amount of information available for each study area (Figure 4). At the top of the list are the North Slope Study lakes that were monitored and observed throughout the lifetime of the project. The watershed areas, meteorological parameters, and recharge processes of these lakes are the best understood of all the lakes studied in the North Slope Lakes project. Directly below this category are the 2008 Ice Road Lakes. These lakes were primarily monitored during the 2007-2008 breakup period when periodic site visits were possible. Finally, there are the NPRA test lakes. These are lakes located the farthest to the west in NPRA, and were rarely visited in the field. These three categories of information appropriately represent a real life scenario where varying levels of data were available in different regions.

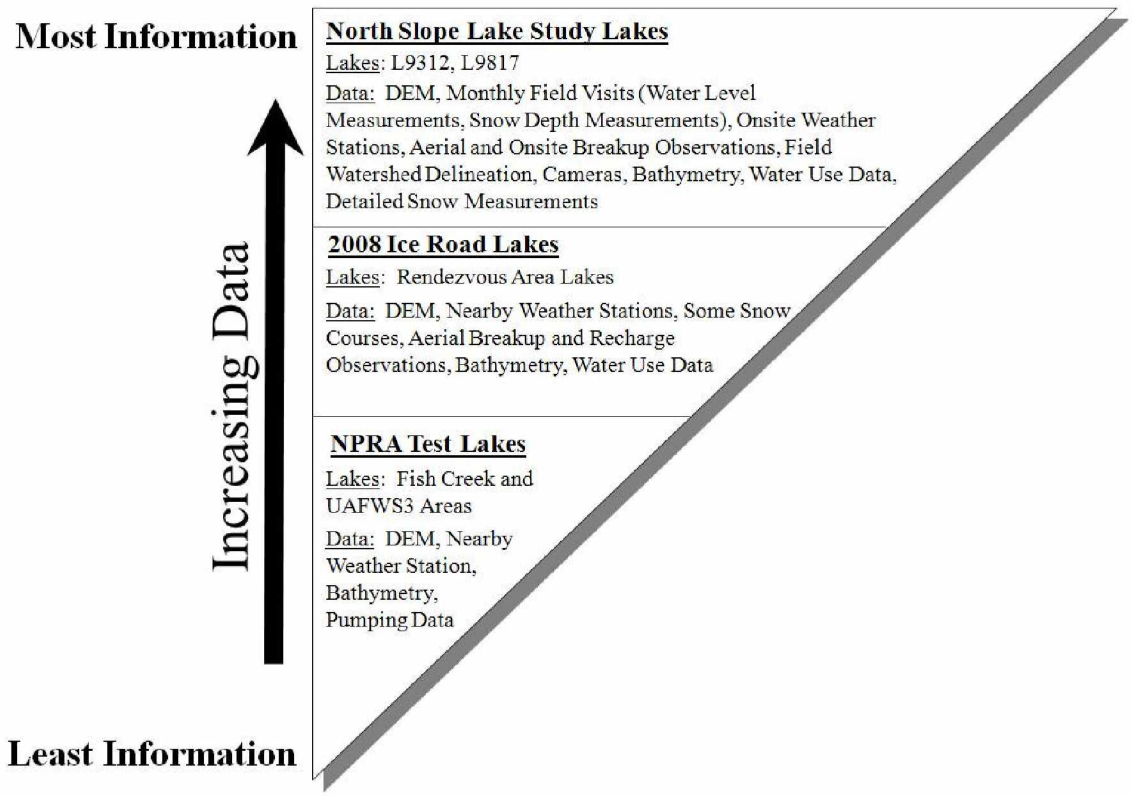


Figure 4 – Study lakes categorized by level of available information.

As will be further discussed in the *watershed delineation* section, a slightly different method of categorization was used when digitally delineating watershed areas. In short, five distinct areas were defined for watershed analyses. These regions were named: UAFWS3 Area, Fish Creek Area, Rendezvous Area, L9312 Area, and L9817 Area (Figure 5). To minimize confusion, Table 1 summarizes how the watershed delineation organization of lakes fit into the three main categories of classification.

These levels of classification are also displayed in the regional study site aerial image (Figure 5).

Table 1 - Summary of lake classifications.

North Slope Lakes Study Lakes		2008 Ice Road Lakes		NPRA Test Lakes	
L9312 Area	L9817 Area	Rendezvous Area		Fish Creek Area	UAFWS3 Area
Lake L9817	Lake L9817	Z06005	M9912	Z06004	M0403
		Z06006	M0254	M0305	M0404
		M0024	M9913	M0306	M0405
		R0071	M9922	M0304	M0406
		M9914	M9923	M0303	M0407
		M0256	M9925	M0307	M0408
		M0255		M0302	M0409

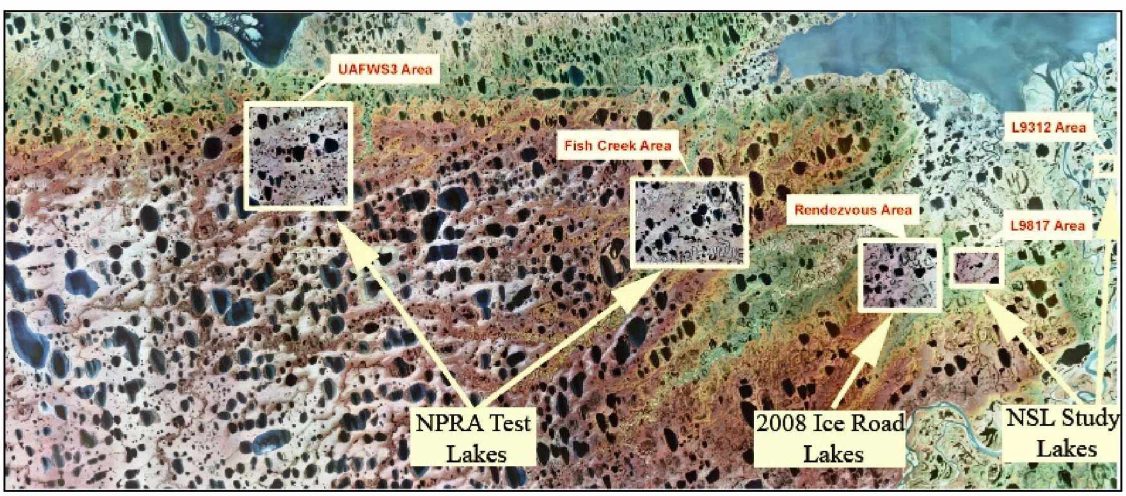


Figure 5 – Study areas within NPRA (Scale: 1 cm = 7 km).

North Slope Lakes Project Study Lakes

As discussed in the introduction, Phase 1 of the North Slope Lakes project consisted of six primary study lakes. Of these six lakes, two of them were carried into

Phase 2: Lake L9312 and L9817. These two lakes were most utilized in the formation and calibration of the potential recharge tool. The lakes were studied extensively throughout the project through numerous site visits during winter months. During each of these monthly visits, water levels were surveyed to better understand how water dynamics are affected during winter pumping. Snow courses were conducted at fixed locations to obtain snow water equivalent (SWE) values. Additional data were collected during each of these field trips, varying from month to month.

Increased monitoring took place during the breakup periods of 2005 – 2008. Daily recharge observations were possible at Lake L9312, while periodic visits took place at Lake L9817. Additional snow studies were conducted to obtain more accurate end of winter snow water equivalent (SWE) values. As the snow melted, fixed snow courses took place to observe snow ablation. Water levels were surveyed almost daily to monitor recharge. Various other observations were made daily to gain a better understanding of the water dynamics of these watershed areas.

Lake L9312 (Figure 6) supplies potable water to the Alpine facility and is located directly southeast of the base camp. Moulton classified the lake as a perched lake that is infrequently flooded from the Colville River (Moulton, 2002). The lake is known to have a variety of fish species, however, a special permit allows for up to 30% of the under-ice water to be pumped each winter. The lake is relatively deep with a maximum depth of 4.3 meters (Moulton, 2002). Moulton's bathymetry images of Lake L9312 are included in Appendix A. Since 2004, monthly field work was conducted at the lake to obtain a better understanding of snow distribution, water level dynamics, water chemistry, and general hydrologic behavior. During the 2008 breakup period, cameras were installed at Lake L9312 to observe snowmelt and water level fluctuations. A weather station is located to the northwest of the lake.

Figure 6 - Otrhographic Image of L9312 (Scale: 1 cm = 170 m)

Lake L9817 (Figure 7) is located in NPRA approximately 20 km southwest of the Alpine base camp. The lake is periodically used for ice road construction and maintenance. Moulton classified the Lake L9817 as a tundra lake, as it is isolated and not affected by flood waters. The lake has a maximum depth of 2.8 meters (Moulton, 2002). Lake L9818 is located directly to the west of Lake L9817 and the two lakes are considered to be connected with Lake L9818 overflowing into Lake L9817. Lake L9818 is very shallow (<1.5 meters) and freezes to the ground each winter. Moulton's bathymetric representation of Lake L9817 and L9818 are included in Appendix B. Because of Lake L9817's remote location, monthly site visits were not always possible. When the appropriate snow cover allowed for Hagglunds (track-vehicle) trips, field work was possible. During the 2006, 2007, and 2008 breakup periods, periodic site visits were possible by helicopter. During 2008 breakup, cameras were installed at the L9817 outlet to monitor snowmelt and outflow conditions. A weather station is located directly to the south of Lake L9817.

Figure 7 - Aerial Image of L9817 (Scale: 1 cm = 340 m).

2008 Ice Road Lakes

The 2008 Ice Road lakes (Figure 8) were studied primarily during the 2008 breakup period. The ice road enabled travel to these lakes by truck in March and by Hagglunds in May. The purpose of these visits was to collect additional snow data for this area. During March, several snow courses were conducted along the ice road. Most of these snow courses were repeated during the May visit. The details and locations of these snow measurements are further described in the S*now Data* section. Additionally, aerial photographs were taken of the end of winter snow pack conditions along the ice road to gain a better understanding of the general snow distribution in the area.

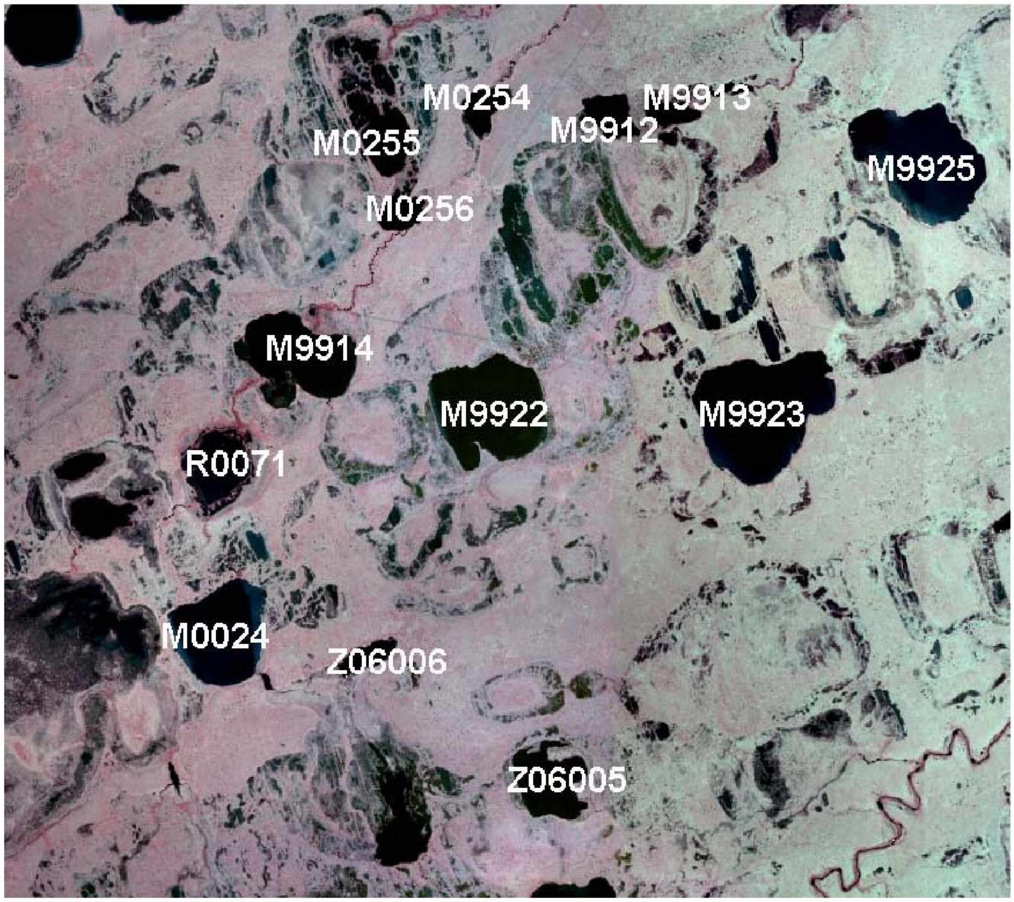


Figure 8 - Orthographic Image of 2008 Ice Road Lakes from Rendezvous Area (Scale: 1 cm = 667 m).

Four helicopter flyovers took place during late May and early June to observe recharge dynamics at six of these lakes: Z06005, Z06005, M0024, M9922, M9923, and M9925. During each helicopter visit, aerial photographs were taken from predefined positions to observe snowmelt and document recharge processes. The photos sought to document full recharge conditions at the lakes, and also develop a protocol for aerially monitoring lake recharge at similar lakes in the future. This qualitative approach of documenting full recharge is currently the most practical method as surveying water levels at many remote lakes is not economically feasible.

At each lake, a photograph was taken from the four cardinal directions and a close-up photo was taken at the outlet location as estimated by the computer program, Rivertools. Rivertools allows users to extract a basin outlet for each lake. These outlet locations were transferred to a GPS, making it easier to locate the potential drainage paths within the lake watersheds. During the initial lake visits, finding the outlet locations was difficult due to snow cover. On the other hand, during later site visits when the tundra was bare, it was much easier to identify the outlets.

Most of these lakes were classified as tundra lakes not subjected to high water flooding. It appears that a few of these lakes may be drainage lakes since stream networks between lakes are often visible. Moulton's bathymetric images for these lakes are included Appendix C. No weather station exists in the direct vicinity of the area, but three weather stations are located nearby. Lake L9817 is approximately 5 km to the east of this area.

NPRA Test Lakes

The NPRA test lakes were split into two sections: the UAFWS3 Area Lakes (Figure 9), and the Fish Creek Area lakes (Figure 10). All of these lakes have been permitted and used for ice road construction and maintenance in the past. These areas are located at a higher elevation and have a slightly rougher terrain. Many of these lakes overflow into adjacent lakes or into local streams. Three weather stations are located close to these study areas and were used in the local meteorological inputs. The UAFWS3 weather station is located in the center of the UAFWS3 Area.

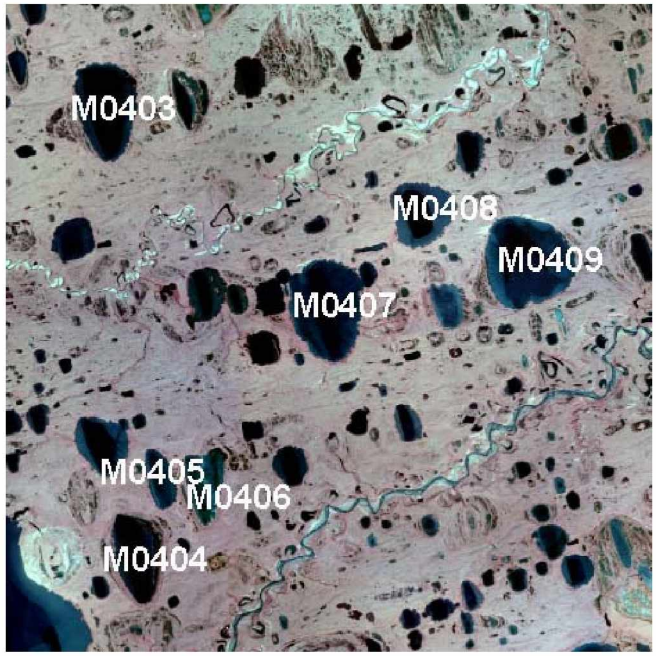


Figure 9 - Orthographic Image of NPRA Test Lakes from UAFWS3 Area (Scale: 1 cm = 1.4 km)

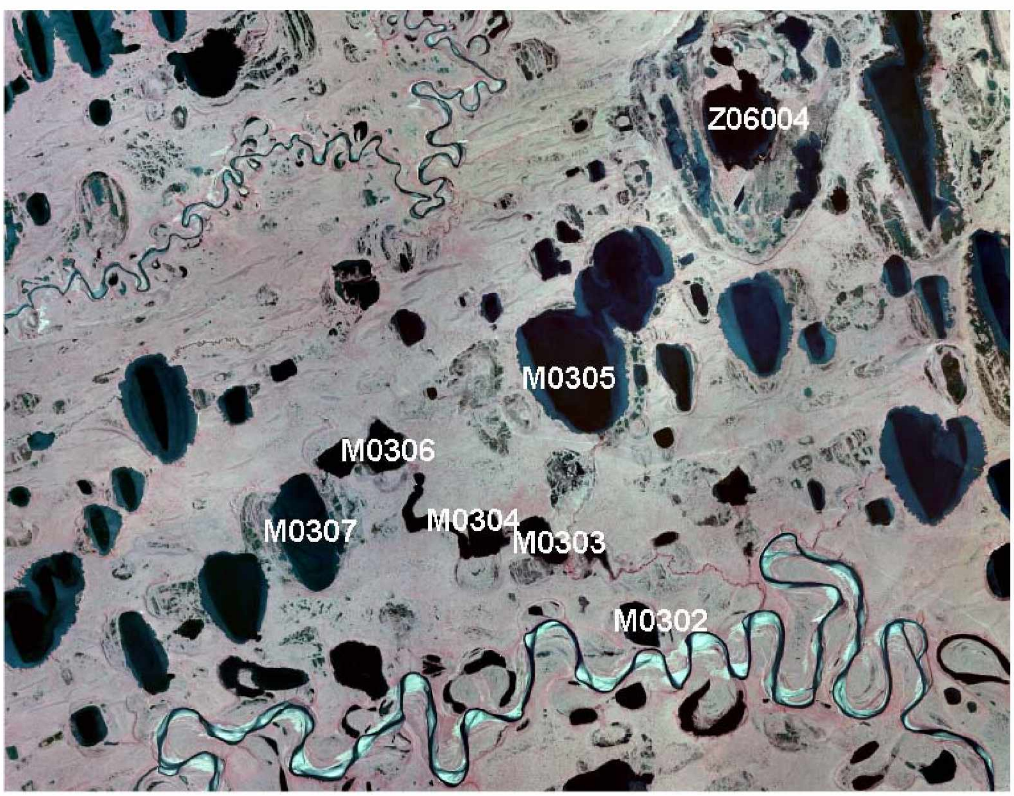


Figure 10 - Orthographic Image of NPRA Test Lakes from Fish Creek Area (Scale: 1 cm = 1 km).

The least amount of information is known about the NPRA test lakes. These lakes were run through the potential recharge tool to demonstrate how predicting potential recharge with a limited amount of data is possible. Knowledge gained from Lakes L9312, L9817, and ice road lakes was valuable when determining the most accurate data inputs to use for this area.

Potential Recharge Equation and Analysis

Quantifying the amount of water available to a particular lake during a specified time period was a valuable measure in the analysis of lake recharge. The most common approach is the water balance method. The simplest form of the water balance equation is given in Equation 1 (Ward and Robinson, 2000).

Equation (1): $I - O = \Delta S$

Where; I = Inflows, O = Outflows, and ΔS = Change in water Storage for a given time

While detailed water balance methods are commonly used in hydrologic studies, potential recharge is a more appropriate term for analysis with the scarcity of data available on the North Slope. Water managers and users in this area may not have a background in hydrology making it important to present data in a way that are easily understood with the user's level of knowledge. These are the two primary reasons a detailed modeling package was not used for this project. While such a model may have the ability to more accurately predict recharge characteristics of lakes, this study site is simply not ready for the level of detail required for most modeling packages. Many of the hydrologic models also require a high level of knowledge in water resources making them less likely to be used by water users on the North Slope. This thesis sought to take the appropriate steps towards introducing hydrologic principles that can be directly applied to water management on the North Slope. The term "potential recharge" is one that a broader audience can grasp and easily calculate with varying amounts of data.

The potential recharge equation (Equation 2) is a rearranged version of the basic water balance equation (Equation 1). The equation separates out the inflows and outflows into two distinct types of data: geographic inputs (i.e., watershed area and lake area) and meteorological inputs (i.e., precipitation, evaporation, and evapotranspiration). This equation is the main driver for the potential recharge tool that will be discussed later.

Equation (2): $$V_R = (A_W - A_L) * (P_a - ET_a) + [A_L * (P_a - E_L)]$$

Where; V_R = potential recharge volume [L^3], A_W = lake watershed area [L^2], A_L = lake area [L^2], P_a = annual precipitation [L], ET_a = annual evapotranspiration [L], E_L = lake evaporation [L].

Watershed Delineation

As seen in Equation 2, the watershed area of a lake is an important parameter in calculating potential recharge. The term "watershed area" is often not clearly defined and can have different meanings in different fields such as biology or ecology. For the purpose of this study watershed area refers to a geographic area where all runoff and subsurface water flows to a specified outlet. While watershed areas can include multiple lakes and can be several square kilometers large, for this thesis, watershed areas were delineated to the smallest scale possible with the goal of producing one unique watershed area for each study lake. For this method, additional runs through Rivertools were often necessary. It was important to recognize when watersheds were connected through stream networks, and appropriately account for this in the potential recharge calculations.

Field Methods for Watershed Delineation

The growth of technology over the past half century has led to many new ways of watershed delineation, most of which are performed remotely on a computer. However, the process of manually defining a watershed has long been practiced by hydrologists. It would be unwise to blindly trust the computer output of resulting watershed areas, especially in a low relief region like the North Slope. The watershed boundary of Lake L9312 was studied in detail for the breakup periods of 2005 – 2008. Many methods were used to obtain the most accurate watershed boundary possible. The region was walked to observe water flow paths and directions while surveys were conducted to find the high areas in the tundra and outlet locations. In the general region of L9312 were several ponded areas where there was a high potential for subsurface and interflow. In these areas, the water levels of the ponds were surveyed to document flow gradients within the shallow subsurface and tundra mat layers. Topographic maps were evaluated to substantiate the results seen in the field. The Lake L9312 watershed area obtained through field methods was compared with the Rivertools results.

Rivertools Methods for Watershed Delineation

Rivertools is a standalone program that can delineate watershed areas (Rivertools Reference Guide, 2001). It was chosen to be used on the North Slope Lakes project for several reasons. The program is relatively cheap compared to other large GIS software packages, making it more attractive for industry use in the future. Rivertools is also very easy to learn with a helpful tutorial that guides one through the processes required to obtain and delineate watershed areas. A digital elevation model (DEM) is required to run Rivertools. A DEM is a digital representation of the ground surface or terrain of the region being analyzed. DEMs are obtained using remote sensing techniques.

DEM datasets are available for most of the United States from the USGS website (seamless.usgs.gov). Most of the accessible data from USGS are at a 60 meter resolution, which means that each 60x60 meter square contains one elevation value within the dataset. DEM data in remote areas, such as the North Slope of Alaska are not currently archived and readily accessible. The North Slope Lakes Project hired Intermap Technologies to create a high resolution DEM (5 meter) so that digital watershed delineation would be possible. In the low relief area of the Alaskan Arctic Coastal Plain, it is hopeful that this high resolution DEM will be of sufficient resolution to accurately delineate watershed areas.

Two products were obtained from Intermap Technologies. The first was a Color Orthorectified Radar Image (CORI) which looks like a color aerial photo. The difference is that the CORI uses radar signals, not sunlight to produce the image. As an airplane flies over the land surface, antennas send signals to the ground with interferometric synthetic aperture radar (IFSAR). The signals return with distance and intensity values that can produce an image with far greater detail than an aerial photograph. All Aerial photographs presented in this thesis are from the IFSAR radar image. The DEM is the second product produced by Intermap. Similar to the CORI, the DEM is obtained with IFSAR technology. Thousands of elevation values are stored as the airplane flies over the ground. The data points in a DEM are stored as a raster file, making them functional in GIS software packages. Since the CORI and DEM are shot from the same airplane, they are automatically georeferenced

IFSAR is a well established remote sensing technique used to produce very high quality elevation data (Intermap Technologies Product Handbook, 2007). The technology interprets electromagnetic energy produced by the land surface. This energy can be either passive energy (like sunlight) or active energy (a radar signal). Aerial photographs typically use the naturally occurring energy from the sun to produce images. IFSAR produces its own illumination through radar pulses generating a more reliable source of data. Intermap uses an airplane (Figure 11) with two antennas attached to the wings at a fixed distance. These antennas produce two synthetic aperature radar (SAR) images that contain the amplitude and wavelength corresponding to the ground surface, with the phase lengths differing due to the distance between antennas. From these images, Intermap creates an interferogram that can derive the final CORI and DEM (Intermap Technologies Product Handbook, 2007).

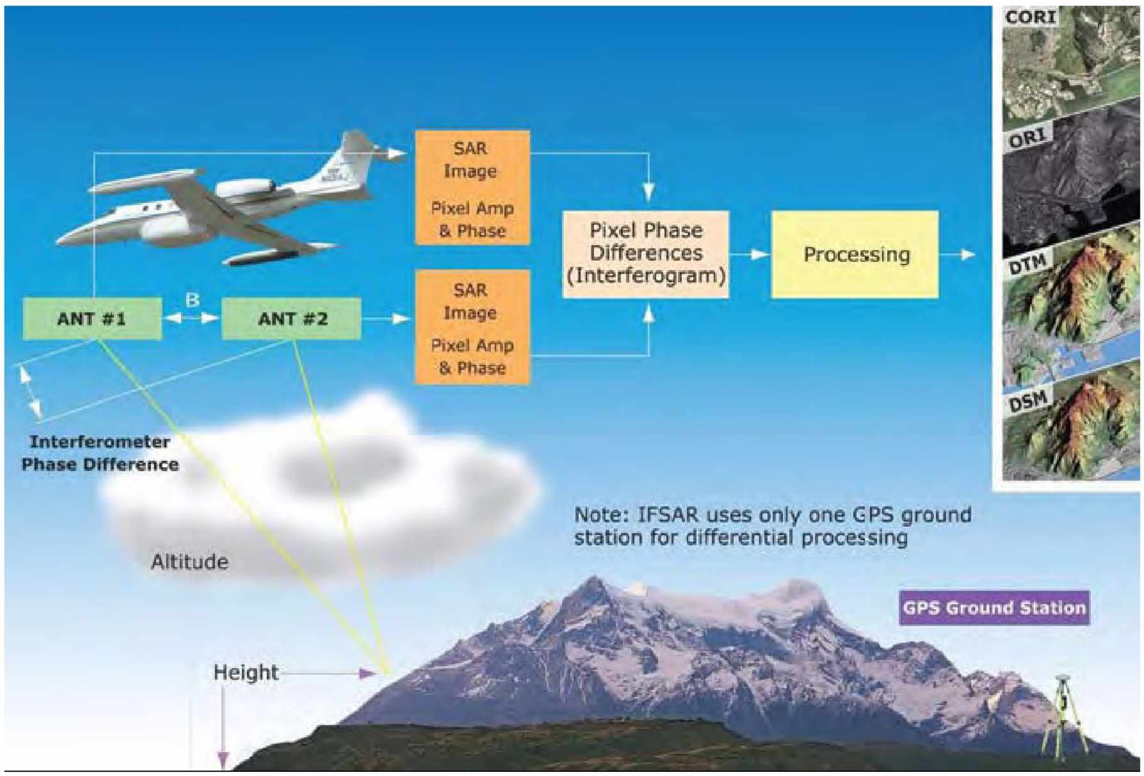


Figure 11 - Intermap's IFSAR system process flow (Intermap Technologies Handbook, 2007)

The north slope of Alaska has relatively low topographic relief (Rovansek et al., 1996), making watershed delineation difficult. Consequently, it is important to confirm the generated watershed areas resulting from Rivertools with aerial and topographic maps. As will be further discussed in the results section, Lake L9312's watershed area was initially delineated from field studies and topographic maps. This watershed closely matched the Rivertools generated watershed, providing some validation for the Rivertools' results on the North Slope. Rivertools output was also compared to a watershed produced with ArcMap in the region, and was found to be similar with areas differing by less that 2%. Thus, Rivertools was used to delineate the remaining watersheds for this study.

The process of delineating watersheds in Rivertools involves five steps:

1. Extraction of flow grid,
2. Identification of basin outlet,
3. Extraction of Treefile,
4. Extraction of River Network,
5. Extraction of Basin mask.

Initially, running the entire DEM through these steps to delineate all the watersheds for the study area was attempted. However, the runtime for such a process was several days and not feasible for proper extraction and calibration of the watershed areas. Therefore, five smaller areas were chosen to be analyzed (Figure 5): L9312 Area, L9817 Area, Rendezvous Area, Fish Creek Area, and UAFWS3 Area. ArcMap was used to cut out these areas from the DEM and prepare them for the Rivertools analysis. For the purpose of demonstrating the methodology of watershed delineation, an example of watershed extraction is shown below for the UAFWS3 Area.

Within the UAFWS3 Area, there are a number of permitted lakes that were pumped for ice road construction in the past. The first step was to determine what lakes were to be analyzed. For this region, seven lakes (Figure 9) were identified as study lakes, requiring watershed delineation. Once the DEM (Figure 12) is properly cut and prepared for Rivertools, the watershed delineation process can begin. The preparation of the DEM is an important step that may need to be done by a GIS analyst. The DEM contains thousands of elevation values, spaced at 5x5 meter squares. Figure 12 displays the elevation values with varying colors; red being the highest and green being the lowest. This shaded relief map can be useful in identifying potential stream networks and general relief change in the area.

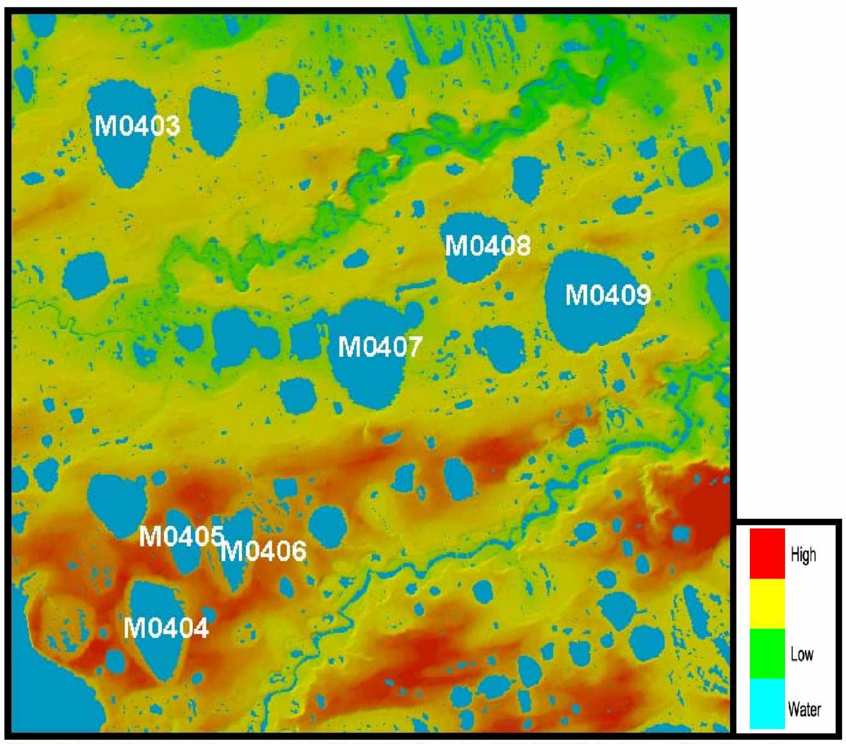


Figure 12 – Digital elevation model (DEM) for the UAFWS3 Area (Scale: 1cm = 1.4 km)

Once the DEM is imported into Rivertools in the correct format, one must extract a flow grid. Rivertools goes through each pixel and determines a flow path for the water based on adjacent pixel elevations. Flow grid extraction only needs to be done once for the entire DEM. After the flow grid extraction is finished, one must define the basin outlet. This is a very important step that must be repeated for each study lake. For example, M0408 has a different outlet location than Lake M0407. Rivertools makes it easy to define basin outlets. One simply clicks on the lake of interest and the flow path is displayed (Figure 13). From this flow path, the user chooses the point closest to the lake body where water is outflowing.

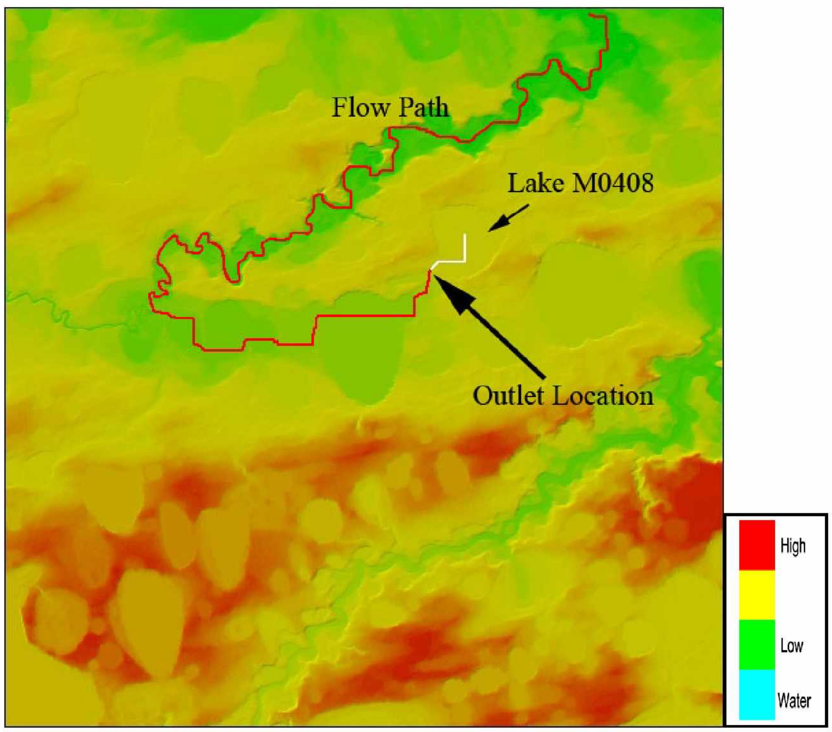


Figure 13 - Basin outlet definition with Rivertools for Lake M0408 (Scale: 1 cm = 1 km)

For each lake, after the basin outlet is defined one must extract an RT Treefile. This step simply creates a vector version of the flow grid for each basin outlet. Finally, a river network can be created which creates stream networks of varying orders. Figure 14 shows streams of 4th order and higher in the UAFWS3 Area.

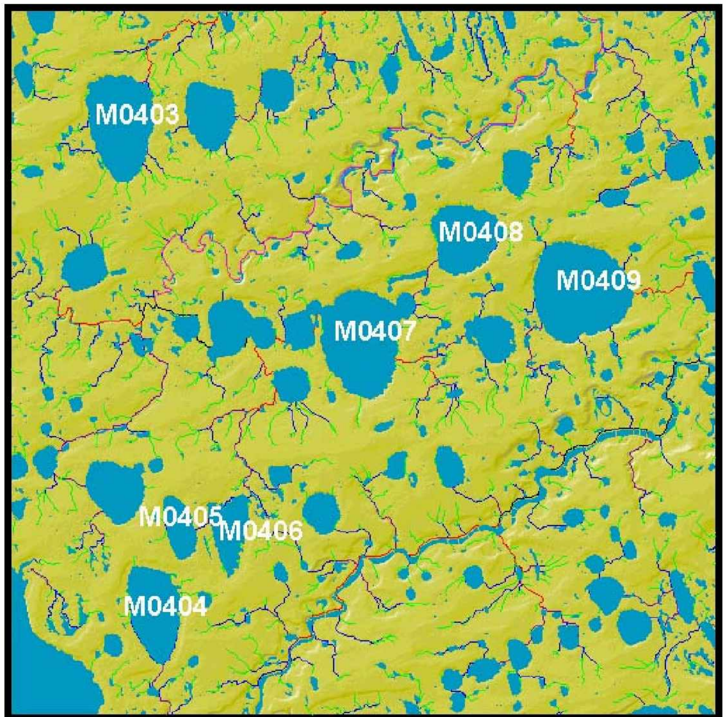
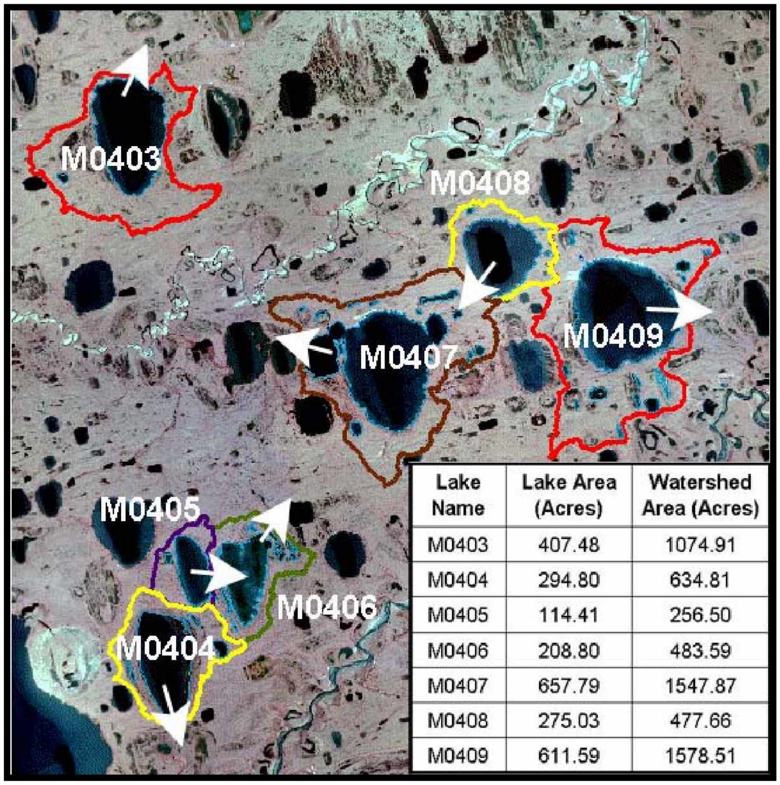


Figure 14 – River network at UAFWS3 Area (4th order streams and higher) (Scale: 1 cm = 1.4 km)

Once the river network is established it is easy to delineate a watershed area for each lake. In Rivertools, one selects to extract a basin mask. After this process is repeated for each lake, the resulting watershed areas are produced (Figure 15). Watershed areas and lake areas are calculated with ArcMap and displayed in the figure. It is also helpful to use the basin outlet tool in Rivertools to see the general flow direction out of each watershed area. This is important for proper potential recharge calculations in later sections.



Lake Name	Lake Area (Acres)	Watershed Area (Acres)
M0403	407.48	1074.91
M0404	294.80	634.81
M0405	114.41	256.50
M0406	208.80	483.59
M0407	657.79	1547.87
M0408	275.03	477.66
M0409	611.59	1578.51

Figure 15 - Final watershed areas and outflow directions for UAFWS3 area (Scale: 1 cm = 1.4 km)

Meteorological Analysis

Data for this project were primarily obtained from weather stations and field trips. As discussed earlier weather data on the North Slope of Alaska are scarce. As a result, the North Slope Lakes project installed several weather stations in NPRA to create a better understanding of the local meteorology.

Weather Stations

Alaska's Arctic Coastal Plain is a large region with few weather stations. Most of the long term reporting stations, like the Betty Pingo weather station are to the east near Prudhoe Bay. It may not be accurate to use data from this area in the NPRA region.

Coastal influences and general east to west weather variability could be significantly different between these two areas. As oil and gas exploration continues into NPRA it will be important to gain a better understanding of the local meteorology. A network of weather stations (Figure 16) was installed as part of the North Slope Lakes project to support water use and tundra travel needs. Data from these stations were used in the calculation of potential recharge estimates.

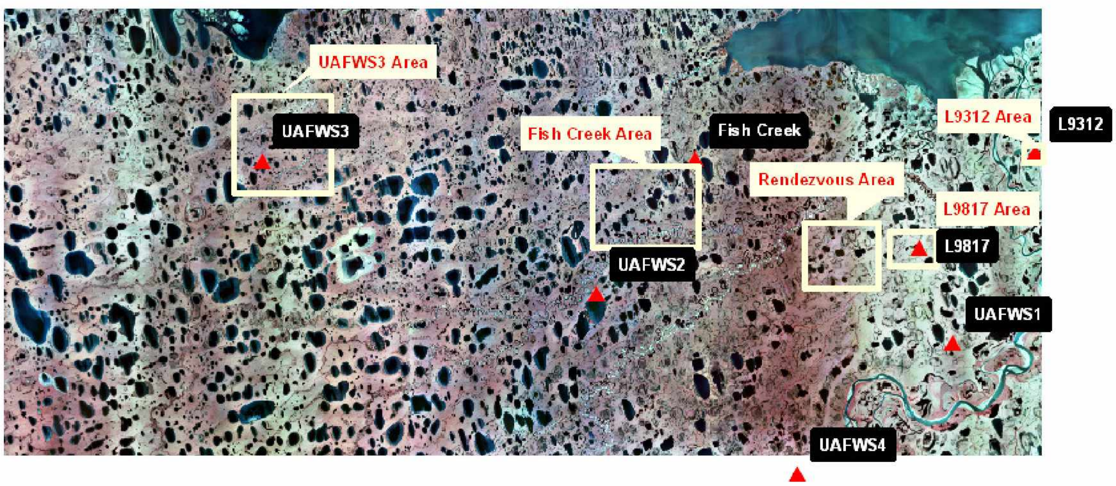


Figure 16 – NPRA Weather Station Network (Scale: 1 cm = 7 km)

While each weather station is somewhat unique, most of the stations generally appear like the one seen below (Figure 17). Solar panels charge batteries that are able to supply power to the stations year-round. This allows the stations to be located in remote areas away from grid power. As seen in the potential recharge equation (Equation 2), the main meteorological parameters required are rainfall, SWE, lake evaporation, and evapotranspiration. For this study, the weather stations were used extensively to obtain rainfall, evaporation, and evapotranspiration values. The snow depth sensors were a valuable tool for analyzing spatial variability in snow pack but the snow grid and snow course data were the primary methods used for estimating SWE. Snow depth sensors were able to collect a snow depth value directly underneath the sensor, but using a single point measurement may not accurately represent the watershed area or entire region (Rees et al., 2005).

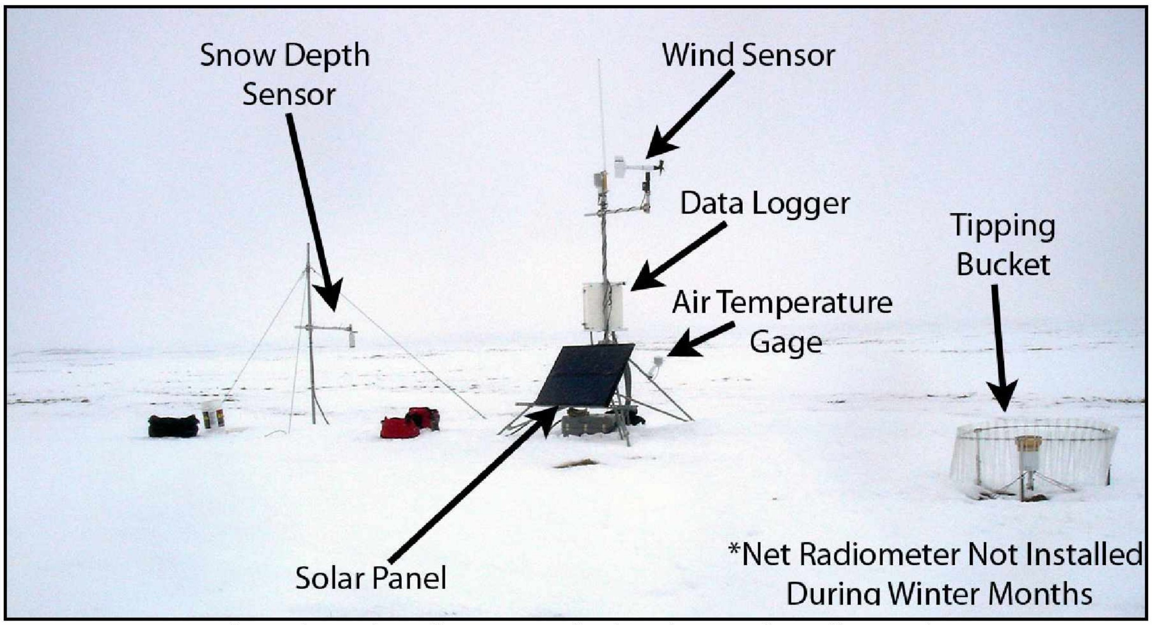


Figure 17 - UAFWS3 Weather Station. (Photo: Chad Cormack)

Rainfall

Rainfall was estimated with tipping bucket gages. While rainfall may occur during late spring and early fall periods, for this study the only rainfall included in the potential recharge calculations was rain during summer months. Mid-winter rainfall events cannot be captured by existing rain gauges. Summer months were determined by looking at average daily temperature graphs for the regions to see when temperature was continuously over freezing.

Precipitation estimates are often underestimated in arctic environments due to instrumentation undercatch (Benning and Yang, 2005). All tipping bucket gages for this study are 0.6 m above the ground and are surrounded by a wind shield to prevent undercatch. The shields surround the rim of the tipping bucket gages to allow for undisturbed rainfall catch during precipitation events. When rain falls into the bucket, it is funneled to a small bucket that tips when filled. Each tip is counted and recorded to a datalogger. Hourly precipitation is calculated and output into a database.

Evaporation and Evapotranspiration

Evaporation is an important input in calculating potential recharge as it often dominates summer water loss. Many studies have used the Priestly-Taylor method (1972) to estimate evaporation rates in arctic climates (Roulet and Woo, 1983; Stewart and Rouse, 1976; Mendez et. al, 1998, Rovansek et. al., 1996). The Priestly-Taylor method is a good approach for estimating evaporation in areas where data are not abundant as it does not require as many inputs as other calculation methods (Mendez et al., 1998). In short, the Priestly-Taylor model (Equation 3) calculates evaporation as a function of air temperature, soil surface temperature, soil temperature (6 cm below surface for this study), and net radiation. Other constants are used as well as an empirically based parameter known as alpha that changes with different land surfaces.

Equation (3): $$Q_e = \alpha(\frac{\Delta}{\Delta + \gamma})(Q_{net} + Q_g)$$

Where; Q_e = latent heat flux (W/m^2), Q_{net} = net radiation (W/m^2), Q_g = ground heat flux (W/m^2), Δ = gradient of saturated vapor pressure (Pa/^{o}C), α = empirical parameter, γ = psychrometric constant (Pa/^{o}C)

An alpha value of 1.26 has commonly been used for open water surfaces (Priestly and Taylor, 1972). The term is not completely understood for high latitude wetlands areas, although some studies have bounded values for this region. A previous study found the alpha term to be 1.29 for open water and 1.56 for arctic wetlands in Canada (Roulet and Woo, 1986). Studies have found that the alpha term decreases over the summer due to less surface water availability as the tundra dries. For wetlands regions, the Rovansek study found an average summer alpha term of 1.30, Rouse's study (1998) found 1.19, and Mendez and other's study (1998) found 1.13. For this study, the sensitivity of the alpha term will be explored as to how it relates to increasing or decreasing overall potential recharge. Other constant values are used in the calculation of evapotranspiration, and are shown in Table 2.

Table 2 - Inputs for ET Calculations

Variable	Definition	SI Units
α	Priestley-Taylor parameter relating actual and equilibrium evaporation.	-
Δ	Slope of the saturated vapor pressure curve	Pa/oC
γ	Psychometric constant	Pa/oC
λ	Latent heat of vaporization	J/kg
ρ	density of air	kg/m3
Cpa	Specific heat of air at constant pressure, 1005	J/kg/oC
d	Depth below the surface	m
Dh	Bulk exchange coefficients for water vapor	m/s
eas	Saturation air vapor pressure	Pa
ET	Evapotranspiration	m/s
Ks	Thermal conductivity of the soil	W/moC
Qnet	Net radiation	W/m2
Qe	Latent heat flux	W/m2
Qh	Sensible heat flux	W/m2
Qg	Ground heat flux	W/m2
Qa	Advective heat flux	W/m2
Ta	Air temperature	oC
Td	Soil surface temperature at depth d	oC
Ts	Surface temperature	oC

Field Data Collection

Physical data collection took place for the duration of the project. During the winter season, monthly trips were taken to the North Slope. The purpose of these trips was to gain a better understanding of the hydrologic and water chemistry characteristics of the study lakes. Annual spring breakup trips were conducted to monitor snowmelt and recharge processes. These trips were typically longer and took place from mid May through mid June. Periodic summer trips were also taken throughout the project.

During the winter trips, several tasks were performed to collect data. While each trip was unique, a uniform set of measurements were taken during Phase 2 of the project. Snow courses, water level surveys, and water chemistry data were collected during each of the winter trips at the study lake locations. The uniformity of these measurements allows for proper comparison of the data.

The spring breakup trip was different from the winter trips. This trip typically occurred from mid May to mid June depending on the timing of breakup. Breakup is the most important time of the hydrologic year. The purpose of the breakup trip was to document the hydrologic dynamics taking place. It was also a good time to obtain the most accurate end of winter SWE data. Full recharge can also be observed and identified for the several study lakes. Table 3 shows the logistics for field trips during 2006-2007.

Table 3 - North Slope Lake Logistics for 2006-2007.

Field Trip	Dates	Trip Objectives
September 2006	Sep. 14th - 21st	Survey, Water levels, end-of-summer field-meter chemistry at all study lakes
October 2006	Oct. 23rd - 30th	Lake freeze-up assessment, Survey, Water levels, Maintenance on data collection sites, BP Field Staff meetings at Milne Point, BPOC
November 2006	Nov. 13th - 20th	Survey, Water levels, field and lab chemistry Alpine and BP area lakes.
December 2006	Dec. 14th - 21st	Survey, Water levels, field and lab chemistry Alpine and BP area lakes
January 2007	Jan. 4th - 15th	Survey, Water levels, field and lab chemistry Alpine and BP area lakes, including K113
February 2007	Feb. 12th - 19th	Survey, Water levels, field and lab chemistry Alpine and BP area lakes
March 2007	Mar. 12th - 19th	Survey, Water levels, field and lab chemistry Alpine and BP area lakes
April 2007	Apr. 12th - 19th	Survey, Water levels, field and lab chemistry at Alpine and BP area lakes
May/June 2007	May 7th - June 15th	Survey, Water levels, field and lab chemistry Alpine and BP area lakes, final chemistry sampling under lake ice conditions for season, snowmelt and lake recharge monitoring

Water Level Surveys

Lake water level is key component for understanding the hydrologic characteristics of tundra lakes. Basic survey equipment (rod and level) was used to obtain water levels. Three local benchmarks were used at Lake L9312. Since the lake provides the Alpine facility with freshwater and is close to the gravel pad, the LCMF survey crew periodically validates these benchmarks to local controls. The Lake L9312 benchmarks are relatively stationary and provide an accurate standard for water level surveys. Since Lake L9817 is more remote, such benchmarks are not available.

Therefore, five benchmarks are used to monitor water levels. While these benchmarks can move due to frost jacking, the monthly site visits and increased number of measurements improves the confidence in the surveys.

At Lake L9312, water is consistently pumped throughout the year. Water levels were obtained during all of the monthly winter site visits. During the breakup period, daily water levels were measured. After snowmelt, and once the lake began to moat around the edges, water levels were obtained with a local staff gauge. During the summer months when field trips were rare, water levels were recorded by the Alpine facility water managers. Water level surveys were obtained at Lake L9817 when site visits were possible. Precise water level surveys were not obtained at the 2008 Ice Road or NPRA Test Lakes.

Snow Data

Snow is a very important input to the potential recharge calculation. In the Alaskan Arctic Coastal Plain, snow typically accounts for 40% of annual recharge (Kane et al., 2000). This large source of recharge melts during spring breakup to replenish the tundra lakes. Many methods are used to quantify the amount of water in the snow and they all must take into account two key parameters: snow depth, and snow density. From these two values, one can appropriately calculate snow water equivalent (SWE). Spatial distribution of SWE across the coastal plain is not completely understood. While gaining a better knowledge of this large scale distribution is important, smaller scale spatial distribution of SWE within single watersheds was analyzed as a starting point.

For the study lakes of L9312 and L9817 it is crucial to obtain accurate SWE values to enable calibration of the potential recharge tool. It should be noted that such accurate SWE estimates may not be obtained for other study lakes or future lakes analyzed. However, in order to test the accuracy of the tool's results, more accurate inputs were used. This level of accuracy can also be seen in the detailed analysis of watershed area delineation for L9312 and L9817.

Several methods of determining SWE were conducted on L9312 and L9817 for comparison. Possible correlations between snow cover on tundra vs. lake should be explored. Below, the various methods of SWE estimation conducted on the two lakes are described. Because potential recharge was calculated annually or seasonally, the end of winter SWE value is the most important to the potential recharge tool since it was only analyzed on an annual or seasonal time step. Therefore, the described methods took place in early to mid May of each year.

Snow Courses

Snow courses took place on the tundra and on the lake. A snow course is an L shaped track where 50 snow depth measurements are obtained (25 depths one direction, then 25 depths along a perpendicular transect). After the snow depth measurements, five snow density samples are taken and weighed in the lab. The 50 snow depths and the five density measurements were averaged to obtain a single SWE value. The weakness of the snow course method is that it is spatially limited to a 25 meter by 25 meter section. If the snow course is conducted in a drifting area, or conversely a low snow area, the results may not accurately represent the entire region of analysis. However, the snow course method is the only method used that explicitly obtains density measurements. In this analysis, the densities from the snow courses were used for each method.

During 2008, snow courses were obtained during the March and breakup field trips along the 2008 Ice Road (Figure 18). Ten snow courses took place during the March trip. While these snow courses did not adequately represent the end of winter SWE, they were still used for recognizing general trends of snow distribution across the study area. During May, six of these snow courses were repeated along the ice road.

At Lake L9312, three end of winter snow course sites exist. They were referred to as the Metsite, Sno1, and Lake snow courses (Figure 19). Immediately prior to breakup in 2007 and 2008, snow courses were conducted at these sites. Due to construction at the L9312 pumphouse in 2008, the Metsite snow course was relocated to a similar area.

At L9817, there were two snow course sites. They are called the Metsite and Lake snow courses (Figure 20). These snow courses were conducted prior to the breakup period for 2007 and 2008 as well. The L9817 Metsite snow course slightly changed location in 2008.

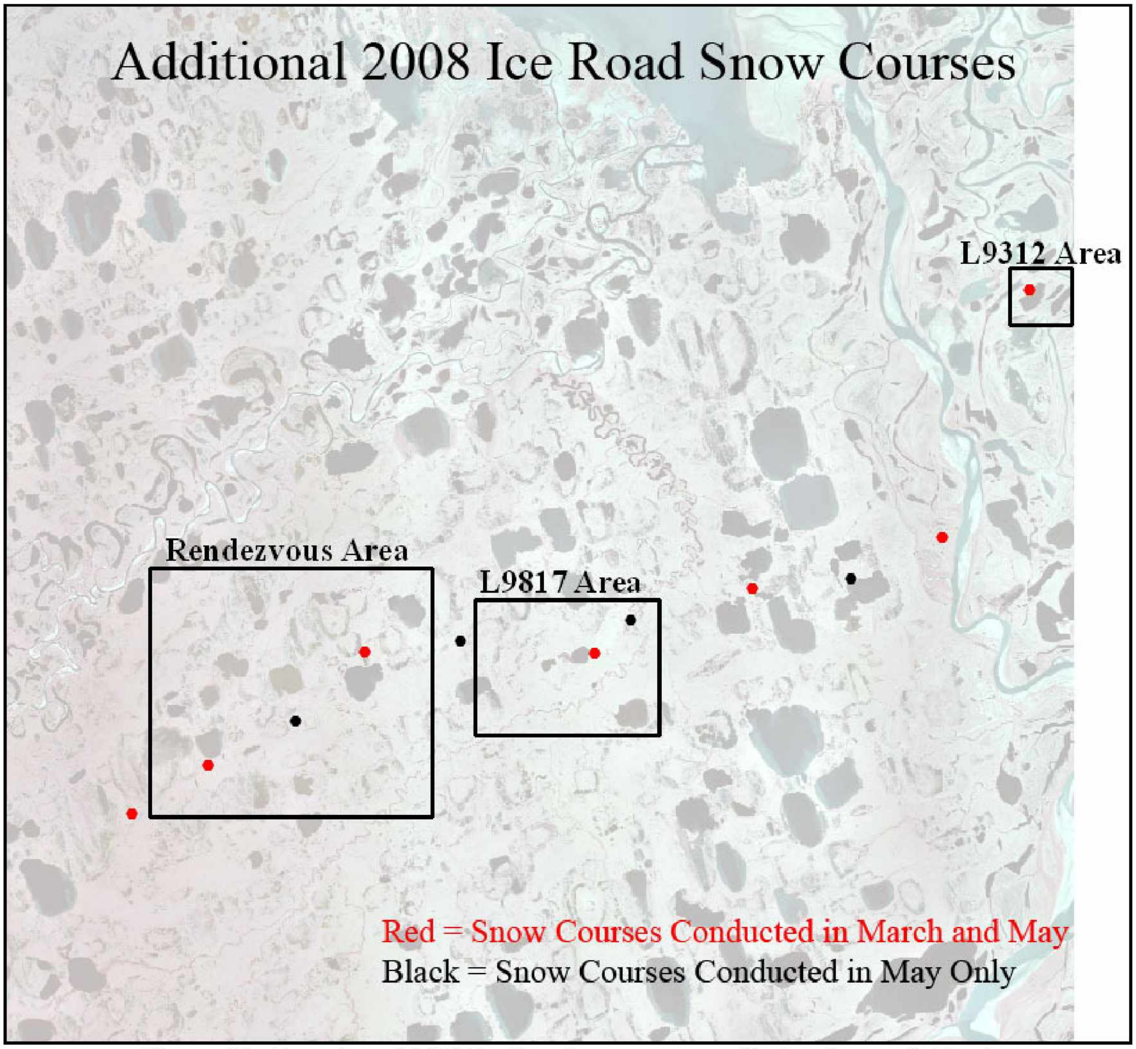


Figure 18 - Location of 2008 Ice Road snow courses (Scale: 1 cm = 2.4 km)

Snow Grids

Snow grids were conducted at L9312 and L9817 prior to the breakup in 2007 and 2008 (Figure 19 and Figure 20). The grids were spaced approximately 500 ft. by 500 ft. and contained snow depths on both the lake and tundra. At each location along the grid, 5 snow depths were taken spaced 1meter apart. The L9312 grid contained 34 nodes (170 depth measurements), and the L9817 grid contained 42 nodes (210 depth measurements).

These 5 depths were averaged to obtain one point value at each node. Each node was saved in a GPS unit so the grid could be reproduced from year to year.

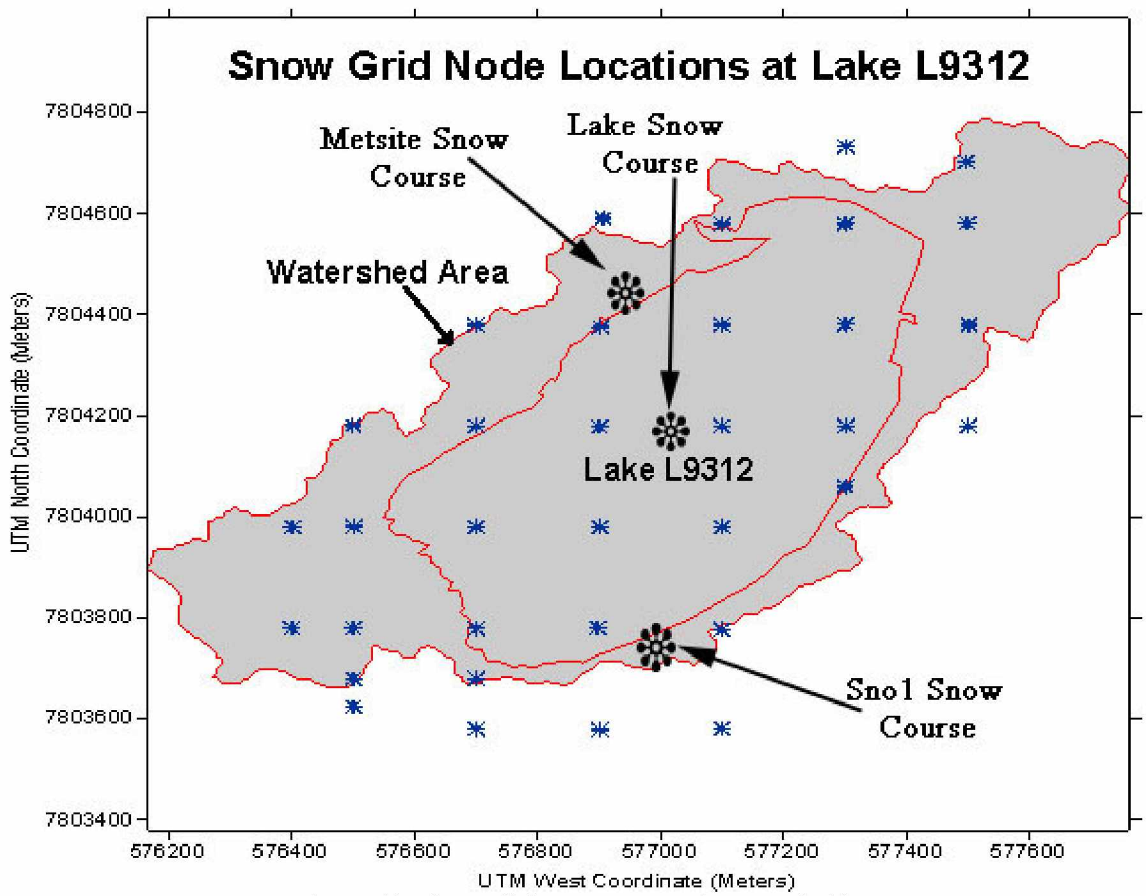


Figure 19 - Snow Grid Depth Locations at L9312.

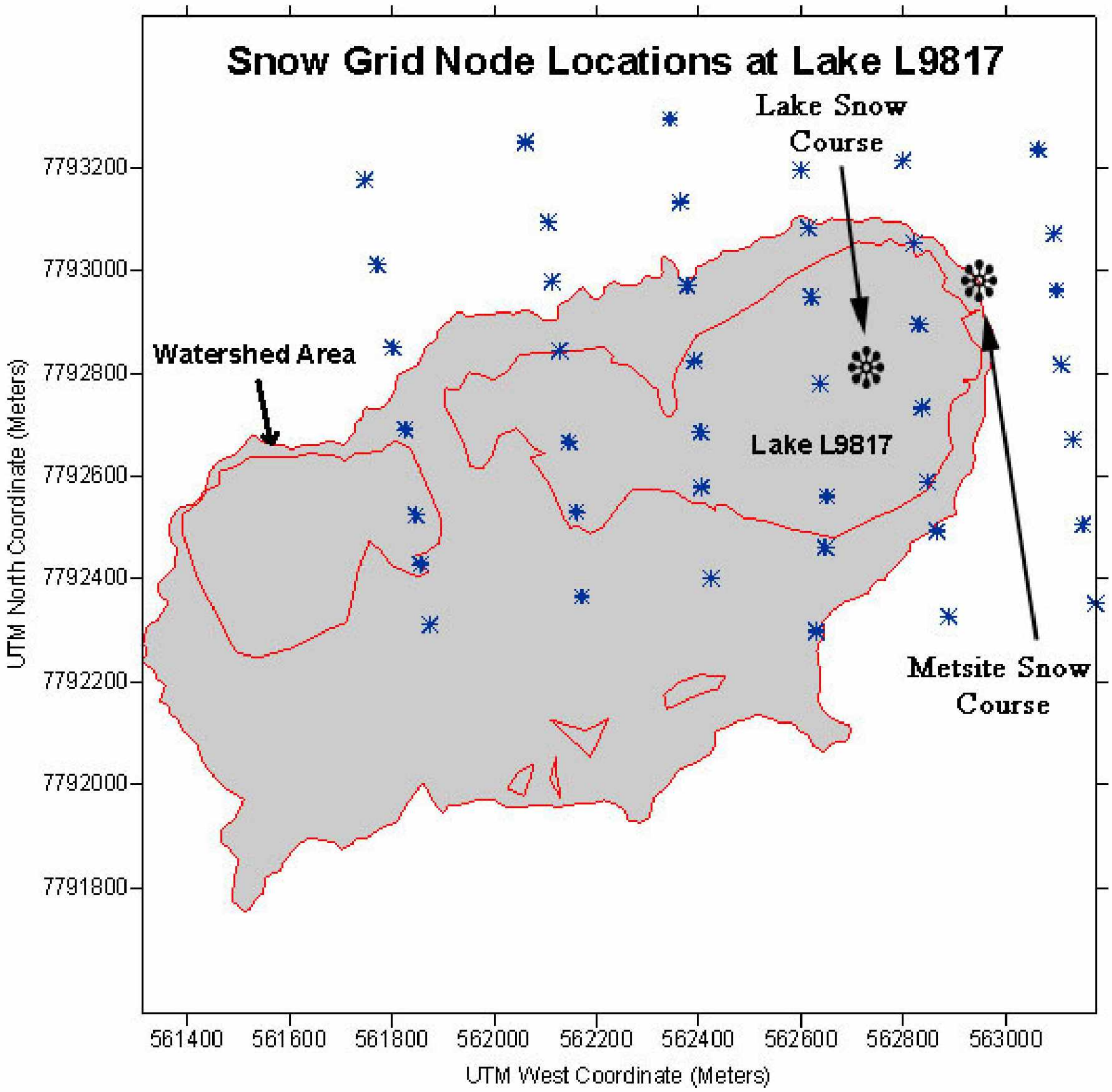


Figure 20 - L9817 Snow Grid Depth Locations.

It should be noted that grid nodes at L9817 were assigned in the field when the exact watershed area was not known. This explains the lack of nodes on the southeastern portion of the watershed. However, the grid nodes outside of the watershed area appeared to represent the snow distribution within the watershed area adequately.

Field Data Processing

As previously described, data in the field were collected during each trip to the North Slope. A three step process was in place for data processing. First, the data were collected in the field and recorded in field books. Each field book was photocopied and filed in a project binder. Next, the data were transferred from the field books to electronic field forms. Field forms were organized by data type. For example, F-011 field forms were for water level surveys and F-012 field forms were for snow courses. This made forms easily searchable and produced continuity between data reports. The last step in data processing for field data was the QAQC. A project staff member checked the field book data with the electronic field form. Final corrections were made, and the field forms were finalized. All forms were organized in the appendices of monthly data reports for the North Slope Lakes Project.

Potential Recharge Tool

As has been previously mentioned, current water management by the petroleum industry is not always adequately informed by hydrologic principles. The calculation of potential recharge is a good first step towards incorporating hydrology into the water use practices. While the potential recharge equation is not necessarily a complicated calculation, it would be beneficial to have a tool that can quickly and easily calculate values. Such a tool would also have the possibility of organizing water permit data. Unlike many complicated models, a tool can be directly and quickly applicable to a number of study areas. The simplicity also lends itself to being usable by a wider audience, not only hydrologists.

Such a tool was developed in Microsoft Excel Visual Basic for Applications (Excel VBA). Developing the tool in Microsoft Excel allows anyone with access to Excel to use it. The tool is also small and easily transferable through e-mail or USB thumb drives.

A flow chart for the tool can be seen in Figure 21. The tool is designed to be easy to use and manipulate for the user's individual purpose. When the tool is initially opened, the user first chooses the desired period of analysis: annual or seasonal. Eventually, a monthly time scale option may be developed for the tool, but right now these are the only options. The annual period of analysis simply lumps all weather and water use data into one potential recharge calculation. The seasonal analysis separates inputs and outputs into two sections: summer and winter. If the user only wants to run the tool for one season, this would be the desired option.

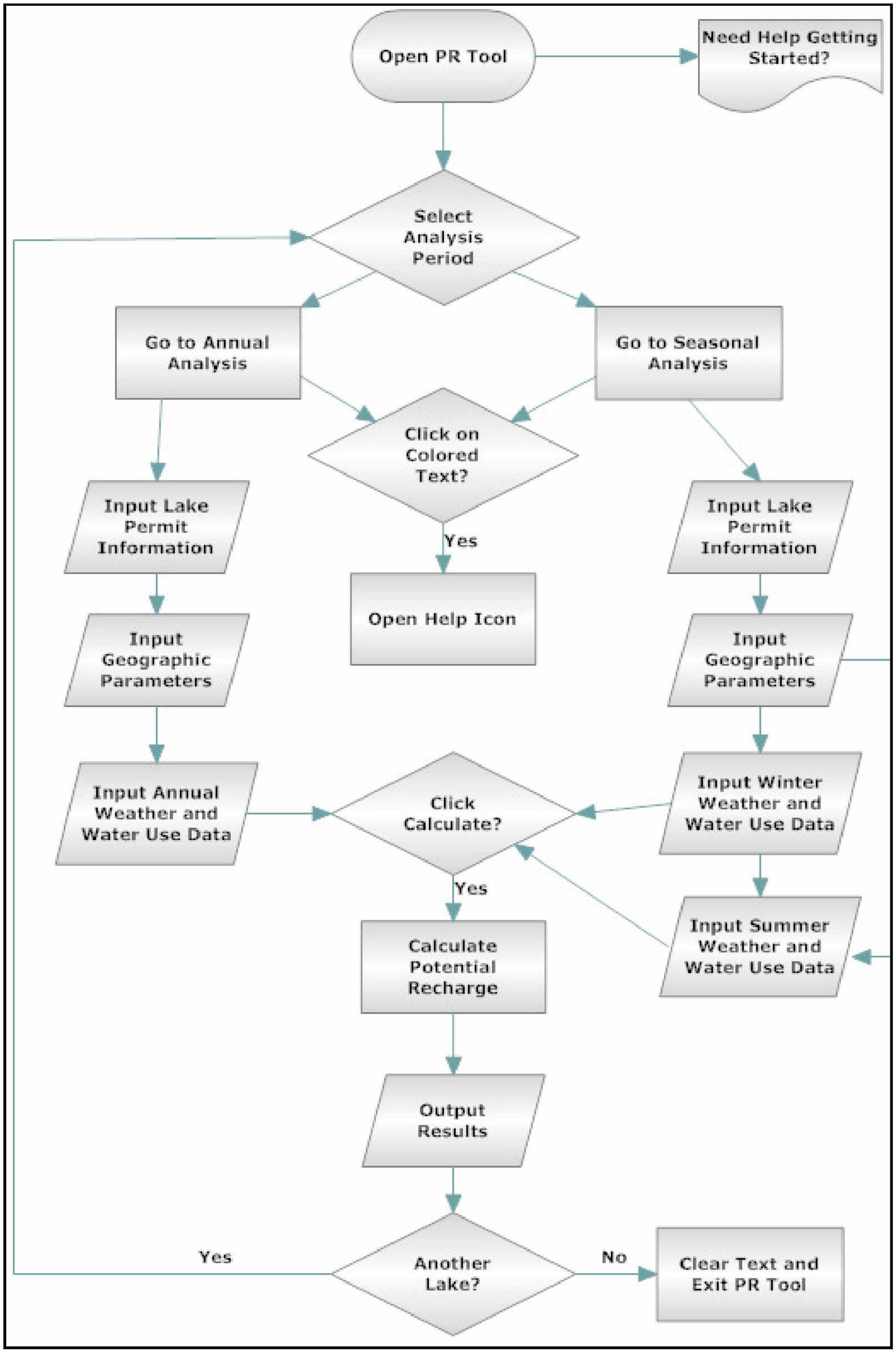


Figure 21 - Potential Recharge Tool Flow Chart

When the tool is opened and the period of analysis is selected, the user is brought to an excel spreadsheet (Figure 22 and Figure 23). Colors were used to help organize this spreadsheet and make it more user-friendly. Cells that are highlighted in light yellow require user input. Any text that is colored (not black) can be clicked on to have a help icon pop up. For example, if a user does not know what a watershed area is, he could click on the green text that says “Watershed Area” and a popup icon within Excel would come up, giving the definition of a watershed area. This feature is especially useful in the weather data inputs because if the user wants to know typical values for the North Slope area, they will be given in these help icons.

The annual and seasonal spreadsheets both contain three sections. The first section is titled “Lake Permit Information.” This section is simply for organization purposes and none of the user inputted data in this section will be included in the calculation of potential recharge. The second section is titled “Potential Recharge Calculator” and is the area where the user inputs the parameters used for calculations. Inputs can be entered in several different units, chosen from the adjacent drop down menus. The third section is titled “Results”, and this is where the calculated values are displayed. This box contains three control boxes that perform different tasks. The first is the calculate button. When the user presses this button, all of the results are calculated and output. The next button is the “Output to New Tab” button. When this button is pressed, the current page is copied and placed in a new tab. This allows the user to easily print results for multiple lakes in one Excel workbook. The final button is the “Clear” button. This button clears all the user input and results so that the tool can be used for a new lake. All results are given in units of Million Gallons (MG).

Each of the regions in this study will be run through the potential recharge tool. Results will be summarized in tables at the end of each region's section. The actual potential recharge output pages for each lake can be seen in Appendix A.

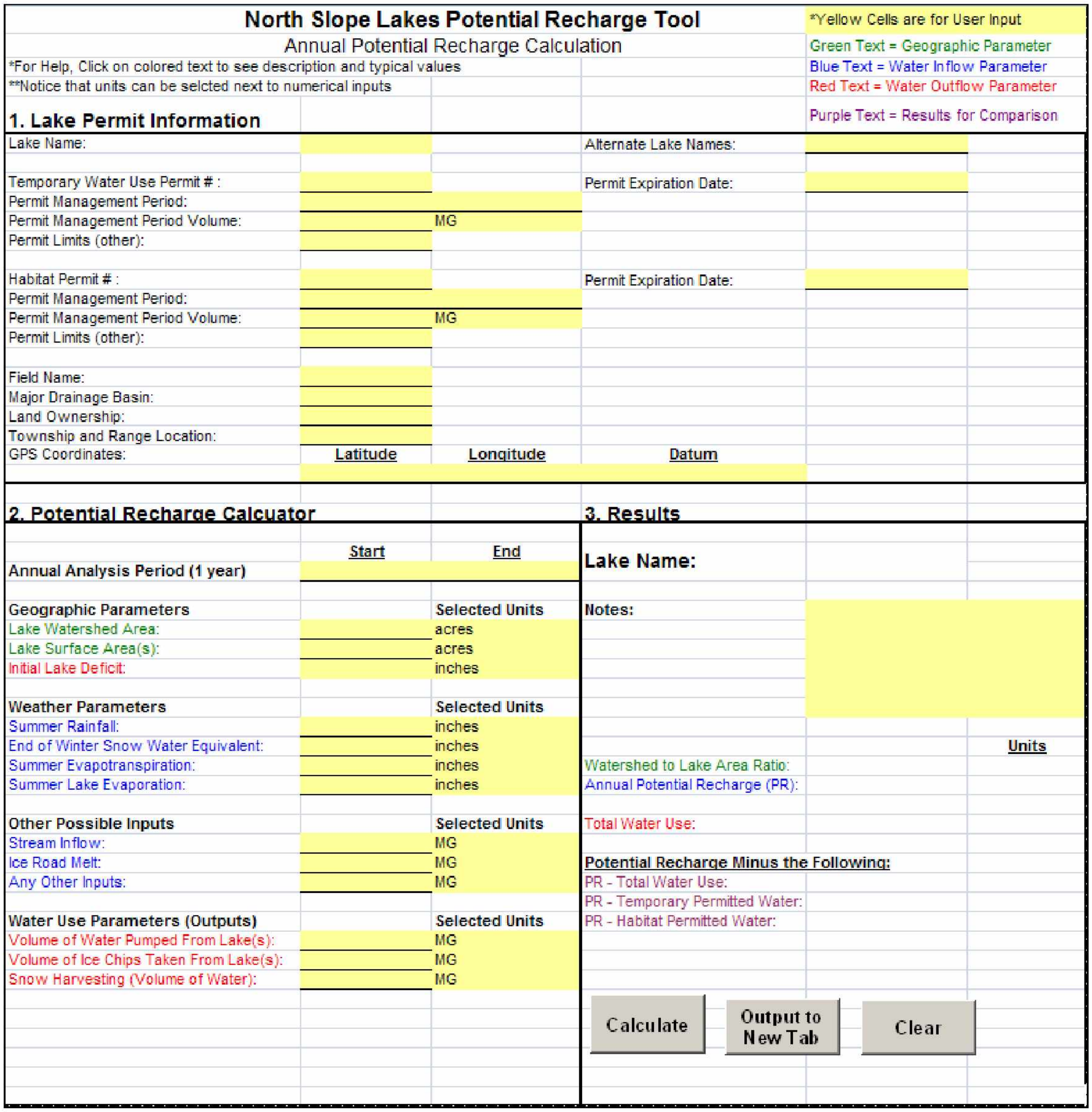


Figure 22 – Annual analysis screenshot of potential recharge tool.

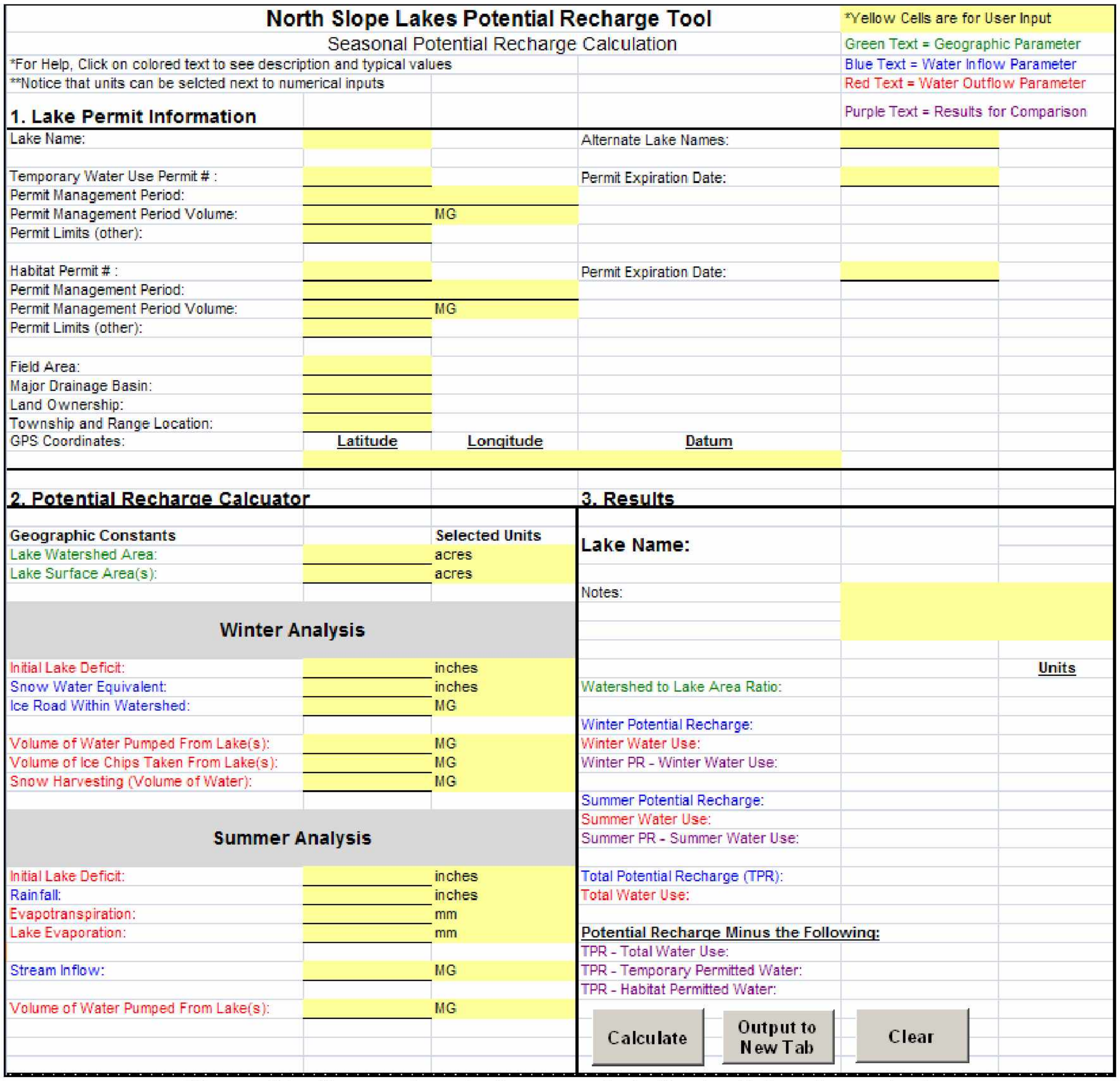


Figure 23 – Seasonal analysis screenshot of potential recharge tool.

Results and Discussion

Spatial Distribution of Data

Determining how to spatially apply meteorological data across the slope is a difficult task with a limited amount of data available across such a large region. The three main weather inputs (snow, rain, and evapotranspiration) must be applied to each study lake for the potential recharge calculation. Rain and evaporation data are available from the weather station network. Snow data are more difficult to quantify and has mainly been studied in the eastern study regions. The NPRA study lakes do not have any snow data available with the exception of the one point depth measurement from the snow depth sensors.

The primary method of distributing weather data to the study regions will be the Theissen Polygon Method (Thiessen, 1911). This general method has been commonly used in hydrology (Chin, 2006). The method creates polygons that overlay the lakes in the region based on their proximity to weather stations. The lake being analyzed was covered by the data from the closest weather stations. This method is static from year to year, and does not change with varying weather conditions. While it may not be the most accurate method of analysis, in a large region with such limited weather stations it is an appropriate method of distribution. Rainfall data were available for all of the reporting stations, while evaporation calculations were only available at three of the stations. The resulting Theissen Polygon maps can be seen in Figure 24 and Figure 25. These figures will be referenced when applying the rain and evaporation values to the study lakes under analysis.

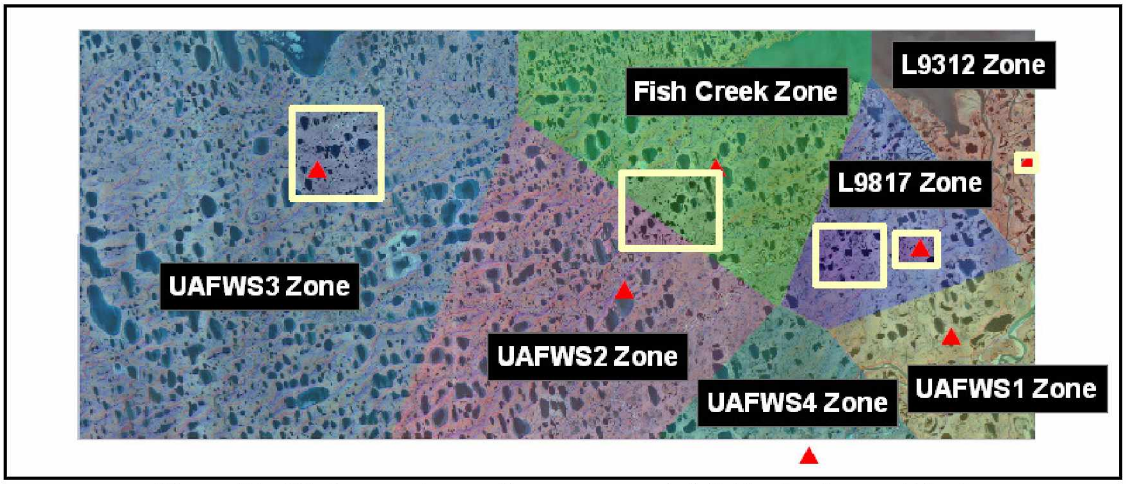


Figure 24 - Theissen polygons for summer rainfall (Scale: 1 cm = 7 km)

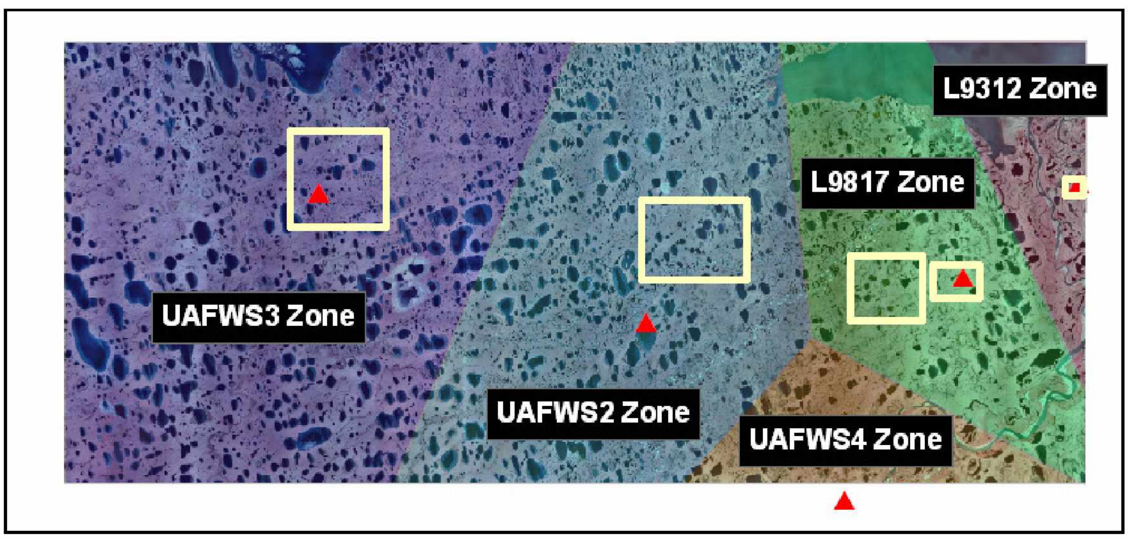


Figure 25 - Theissen polygons for evapotransiration (Scale: 1 cm = 7 km)

North Slope Study Lake Areas

For each of the three study lake areas (NSL study lakes, 2008 ice road lakes, and NPRA study lakes) it was demonstrated how to determine the proper geographic and meteorological inputs to calculate potential recharge. Lakes L9312 and L9817 were the most researched lakes in this study. The results from these lakes were used to calibrate and determine proper inputs for the other two categories of study lakes.

Watershed Areas

Watershed delineation initially took place through field efforts alone at Lake L9312. After the observations from the breakup periods of 2005 – 2007 the watershed boundary of Lake L9312 was estimated to be 0.80 km^2 (Figure 26). Rivertools analysis delineated the watershed area for Lake L9312 and found it to be 0.89 km^2 (Figure 26). These watershed areas only differed by 0.09 km^2 providing some validation of the Rivertools analysis.

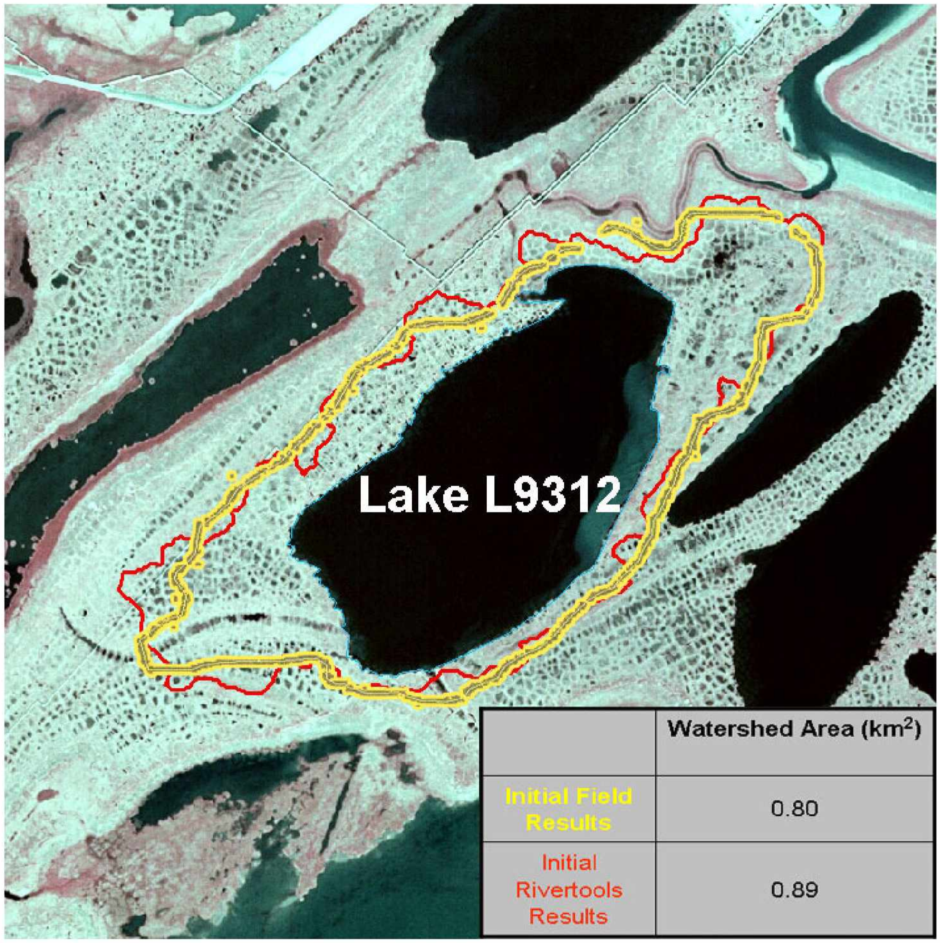


Figure 26 – Initial results for watershed delineation of Lake L9312 (Scale: 1 cm = 170 m)

The results for water balance calculations of Lake L9312 in the past were consistently showing that Lake L9312 was not fully recharging, when in actually it was. For this reason, further field efforts were performed to look for the source of error in these results. During the 2008 breakup period field observations and measurements opened the door to a potential increase in the area of the Lake L9312 watershed. It was hypothesized that the neighboring Lake L9311 could possibly drain into Lake L9312 during the summer months through the matte layer and growing active layer. Water level surveys of Lakes L9312 and L9311 showed a clear gradient between the lakes. Soon after snowmelt, the region between Lake L9312 and Lake L9311 was very wet with water generally flowing towards Lake L9312. Water level surveys also indicated a similar gradient between Lakes L9311 and L9310 with observations documenting flowing water going towards Lake L9310 as well. Lake L9311 had no visible surface outlet during breakup.

Recognizably, a detailed analysis of subsurface and matte flow was out of the scope of this study; yet this potential subsurface flow could prove to be a significant source of recharge to Lake L9312. Neglecting this source of recharge could adversely impact results for potential recharge estimates. Therefore, it was assumed that half of the watershed area of L9311 would be included in the overall watershed area of Lake L9312 (Figure 27). The other half was assumed to flow towards Lake L9310. Due to lack of information, this is simply a first approximation and future analysis should be done to better define that actual contribution watershed area. Lake area was calculated with ArcMap and includes all visible water surfaces within the final watershed area.

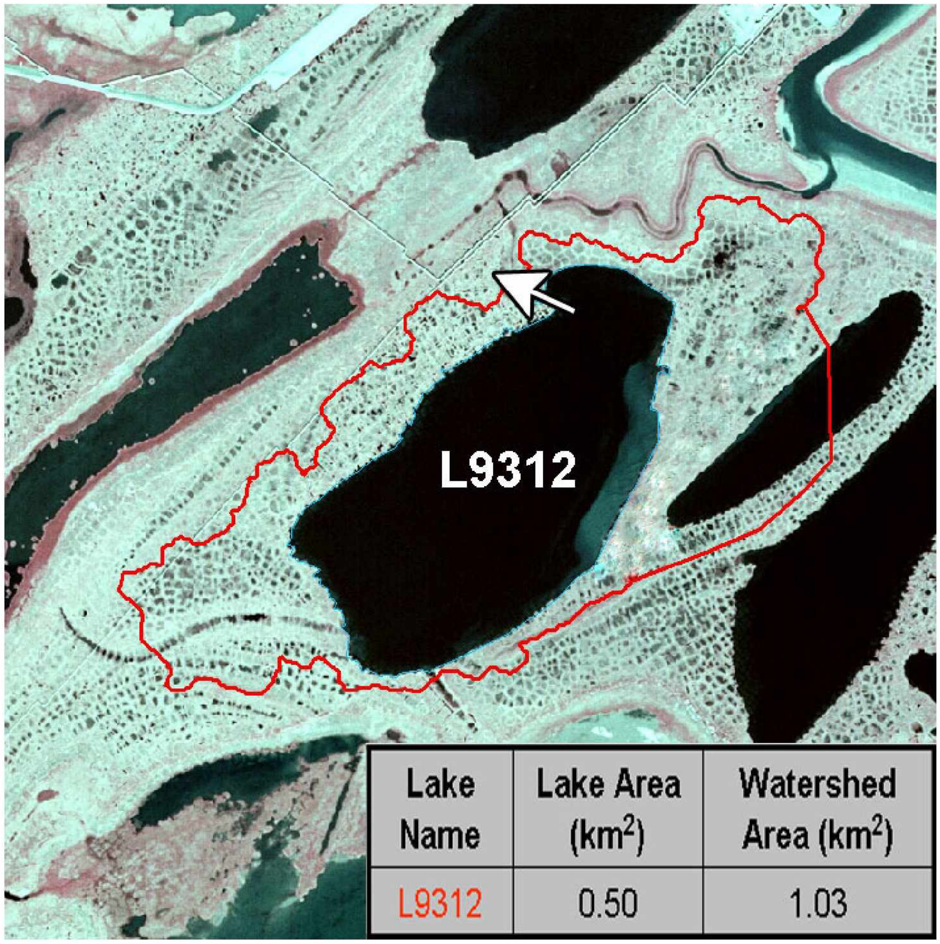


Figure 27 – L9312 Area final watershed area and outflow direction (Scale: 1 cm = 170 m).

The final watershed area for Lake L9312 was calculated to be 1.03 km^2 with the lake area taking up about 50 % of this region. The control outlet for Lake L9312 has no clear definition, but rather a wide marshy area. This made defining a clear lake-full elevation difficult.

Opposite to Lake L9312 methods, the watershed area for Lake L9817 was first delineated with Rivertools and then verified with field observations. Rivertools produced a watershed area that included the adjacent Lake L9818. Lake L9818 is a shallow unpumped lake that was observed flowing into Lake L9817 during the breakup period for

2008. Rivertools watershed delineation included both lakes in the watershed area of Lake L9817 (Figure 28). Since Lake L9818 is unpumped and a clear connection exists between the lakes, the resulting watershed area was accepted. Lake area was calculated with ArcMap, and included all visible water surfaces within the watershed area.

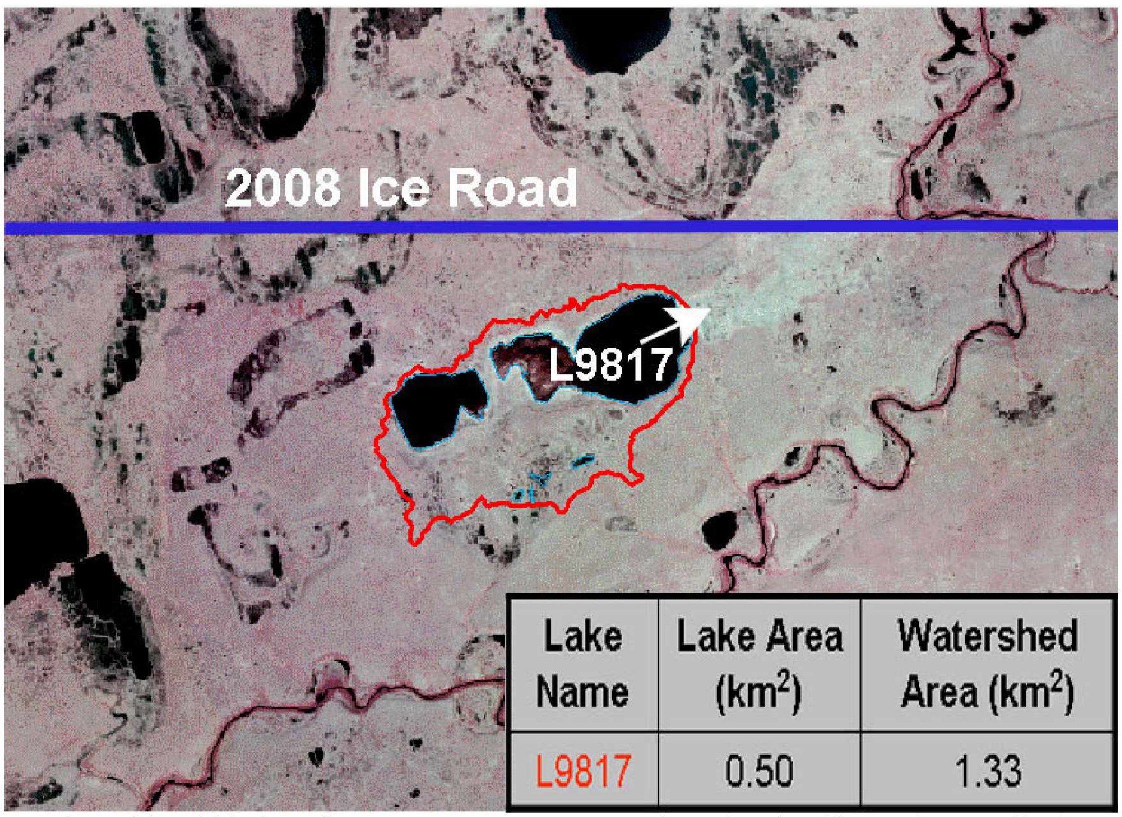


Figure 28 - L9817 Area final watershed areas and outflow direction (Scale: 1 cm = 340 m).

The watershed area for L9817 was calculated to be 1.33 km^2 with 37 % being covered by water bodies. The lake has a very clear stream that outflows towards the east when the lake is overfull.

Snow Water Equivalent

The snow water equivalent (SWE) for the watershed areas of these lakes was the most difficult parameter to estimate. Three methods for estimating SWE are compared: snow depth sensor estimates, snow course estimates, and snow grid estimates. Values for these three methods were calculated for 2007 and 2008 at Lakes L9312 and Lake L9817 (Table 4 and Table 5). The snow depth sensor only contains a single point measurement, the snow course measurement contains 50 depth measurements spread over a 25 X 25 meter L-shape, and the snow grid contains depth measurements spread over the entire watershed. From 2007 to 2008 at Lake L9312, the snow depth sensor and snow depth sensor were moved because of construction at the Lake's pumphouse. By moving these locations, a large drop in SWE was seen between the years, while the snow grid estimate was fairly consistent. This illustrated how the SWE changed in different areas of the watershed area. Choosing a snow course or sensor site that appropriately represents a large watershed area region is difficult and in some cases not possible. The snow grid method appeared to better capture SWE for the Lake L9312 watershed area. Lake L9817 results showed a similar disparity. From 2007 to 2008, the snow sensor and snow course SWE measurements decreased, while the snow grid SWE estimation increased. The snow grid SWE estimations were used for the final potential recharge estimations.

Table 4 - 2007 SWE Comparisons for Lakes L9312 and L9817.

Lake L9312 Snow Data Comparison 2007

	Depth	Percent	Density	*Contributing SWE (cm)	Total SWE (cm)
Snow Depth Sensor					
	52.30		0.32	16.74	16.74
Snow Course					
Lake	18.90	27.16%	0.31	1.37	13.16
Tundra	50.70	72.84%	0.32	11.79	
Snow Grid					
Lake	18.17	28.88%	0.31	1.31	11.72
Tundra	44.74	71.12%	0.32	10.41	

*Tundra accounts for 51.5% of watershed
*Lake accounts for 48.5% of watershed
**All density values come from snow courses

Lake L9817 Snow Data Comparison 2007

	Depth	Percent	Density	*Contributing SWE (cm)	Total SWE (cm)
Snow Depth Sensor					
	31.70		0.29	9.19	9.19
Snow Course					
Lake	19.70	32.62%	0.22	1.63	8.99
Tundra	40.70	67.38%	0.29	7.37	
Snow Grid					
Lake	18.15	31.90%	0.22	1.50	8.51
Tundra	38.75	68.10%	0.29	7.01	

*Tundra accounts for 62.4% of watershed
*Lake accounts for 37.6% of watershed
**All density values come from snow courses

Table 5 - 2008 SWE Comparisons for Lakes L9312 and L9817.

Lake L9312 Snow Data Comparison

2008

	Depth	Percent	Density	*Contributing SWE (cm)	Total SWE (cm)
Snow Depth Sensor					
	24.80		0.30	7.44	7.44
Snow Course					
Lake	11.70	26.71%	0.35	0.95	7.96
Tundra	32.10	73.29%	0.30	7.00	
Snow Grid					
Lake	23.78	34.29%	0.35	1.94	11.88
Tundra	45.56	65.71%	0.30	9.94	

*Tundra accounts for 51.5% of watershed
*Lake accounts for 48.5% of watershed
**All density values come from snow courses

Lake L9817 Snow Data Comparison

2008

	Depth	Percent	Density	*Contributing SWE (cm)	Total SWE (cm)
Snow Depth Sensor					
	25.40		0.32	8.13	8.13
Snow Course					
Lake	18.90	47.13%	0.34	2.42	6.65
Tundra	21.20	52.87%	0.32	4.23	
Snow Grid					
Lake	17.38	29.47%	0.34	2.22	10.53
Tundra	41.59	70.53%	0.32	8.30	

*Tundra accounts for 62.4% of watershed
*Lake accounts for 37.6% of watershed
**All density values come from snow courses

Rainfall

Summer rainfall for Lakes L9312 and L9817 was obtained directly from the onsite weather stations. Since these stations are located directly on the lakes, they provided the most accurate estimate of rainfall for the regions, also being confirmed by the Theissen Polygon rainfall map (Figure 24). Cumulative rainfall plots for the summer of 2007 can be seen in Figure 29 below.

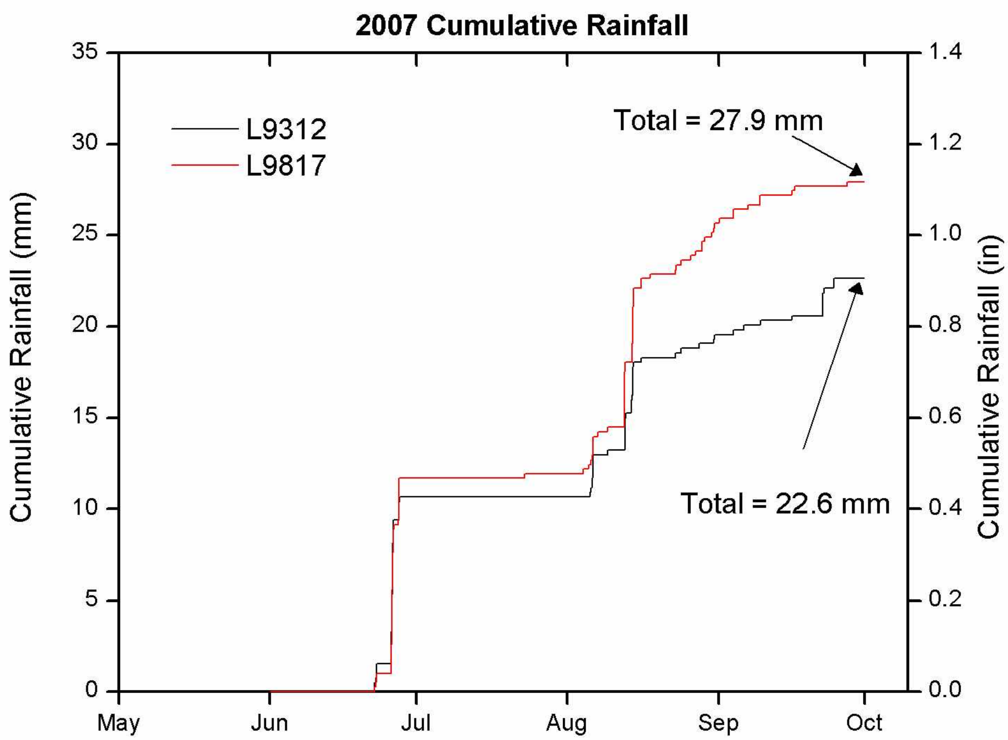


Figure 29 – 2007 Cumulative Rainfall for L9312 and L9817.

As discussed earlier, the summer of 2007 was one of the driest recorded periods on the North Slope. This was represented in the rainfall totals for Lake L9312 and Lake L9817 for 2007. A rainfall amount of 22.6 mm was used for Lake L9312, and 27.9 mm for Lake L9817 in the final potential recharge estimates.

Evapotranspiration

Evapotranspiration for Lakes L9312 and L9817 was calculated directly from the onsite weather stations, as confirmed by the Thiessen Polygons ET map (Figure 25). As discussed in the Methods section, the Priestly Taylor Method was used for estimating evapotranspiration. Three of the weather stations logged appropriate parameters for the evapotranspiration calculation for the summer of 2007 (net radiation, air temperature, soil surface temperature, and soil temperature). Lake L9312 did not report soil temperature, so the nearby L9817 station soil temperatures were input for the calculation. Net radiation and the alpha term are the most influential to the calculation (Mendez et al., 1998) so substituting soil temperatures will not significantly affect the results.

Determining which alpha term to apply to these lakes is important in calculating accurate evapotranspiration for this region. Assuming an alpha that is too low may overestimate overall potential recharge, while using a high alpha term could underestimate recharge. The two most recent studies for empirically determining alpha values on the Alaskan Arctic Coastal Plain are the Rovansek study in 1996 and the Mendez study in 1998 (Table 6). These two studies were conducted around the Betty Pingo area (approximately 100 km east of NPRA). From all studies done for determining alpha values in this region, the Mendez estimations were on the low end, while the Rovansek values represented higher estimations. Both of these estimations were used to calculate ET and lake evaporation (Figure 30 and Figure 31). Deciding upon which value would be appropriate to apply to the potential recharge estimation was difficult. Since the summer of 2007 was dry, it was assumed that the lower Mendez values would be appropriate because less surface water would be available to evaporate. When running the potential recharge tool, it was found that the Mendez values better predicted actual recharge estimates at Lake L9817. The Rovansek values better predicted recharge at Lake L9312 for 2006 - 2007, but impacted the L9817 estimates significantly. Therefore, the Mendez estimations were used in the potential recharge estimates for all of the study lakes for the summer of 2007.

Table 6 - Alpha values for Mendez et al. (1998) and Rovansek et al. (1996) studies

Rovansek (1996) around Prudhoe Bay Alpha Values			
	Wetlands	Lakes	Uplands
Before July 15	1.60	2.00	0.95
July 16 - July 31	1.30	2.00	0.95
After July 31	1.10	2.00	0.95
Mendez (1998) at Betty Pingo Alpha Values			
	Wetlands	Lakes	Uplands
Before July 19	1.15	1.50	0.95
After July 19	1.10	1.50	0.91

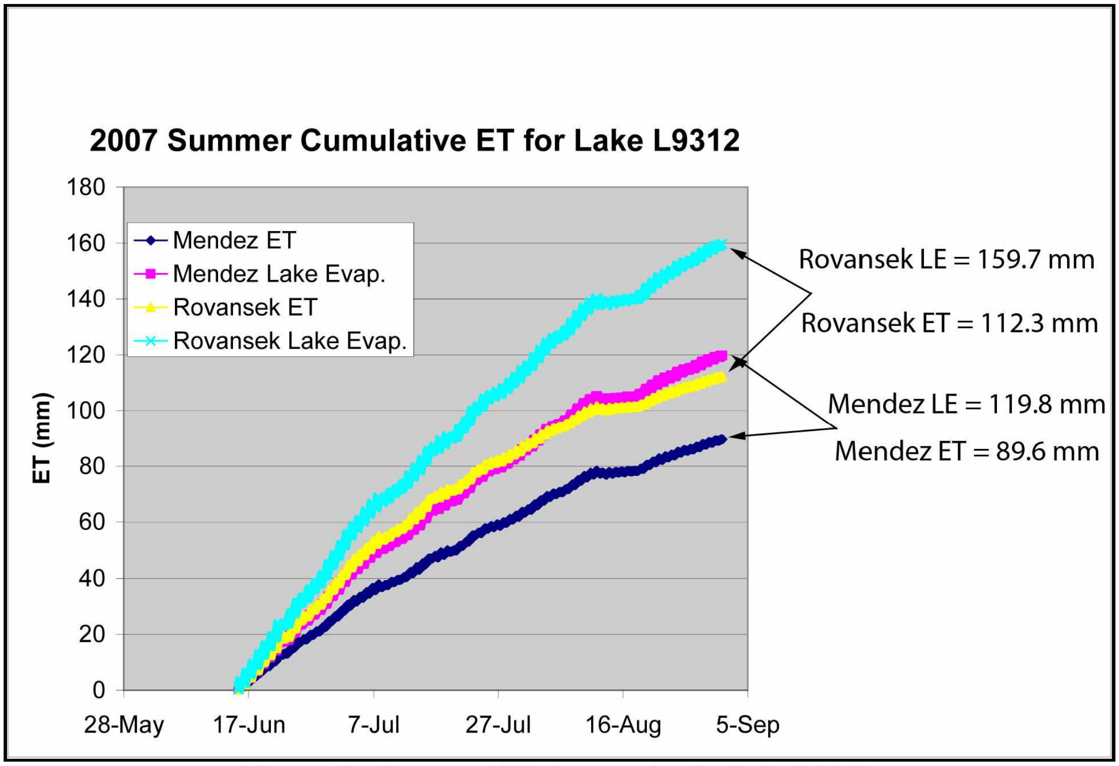


Figure 30 – Summer 2007 Evaporation for Lake L9312.

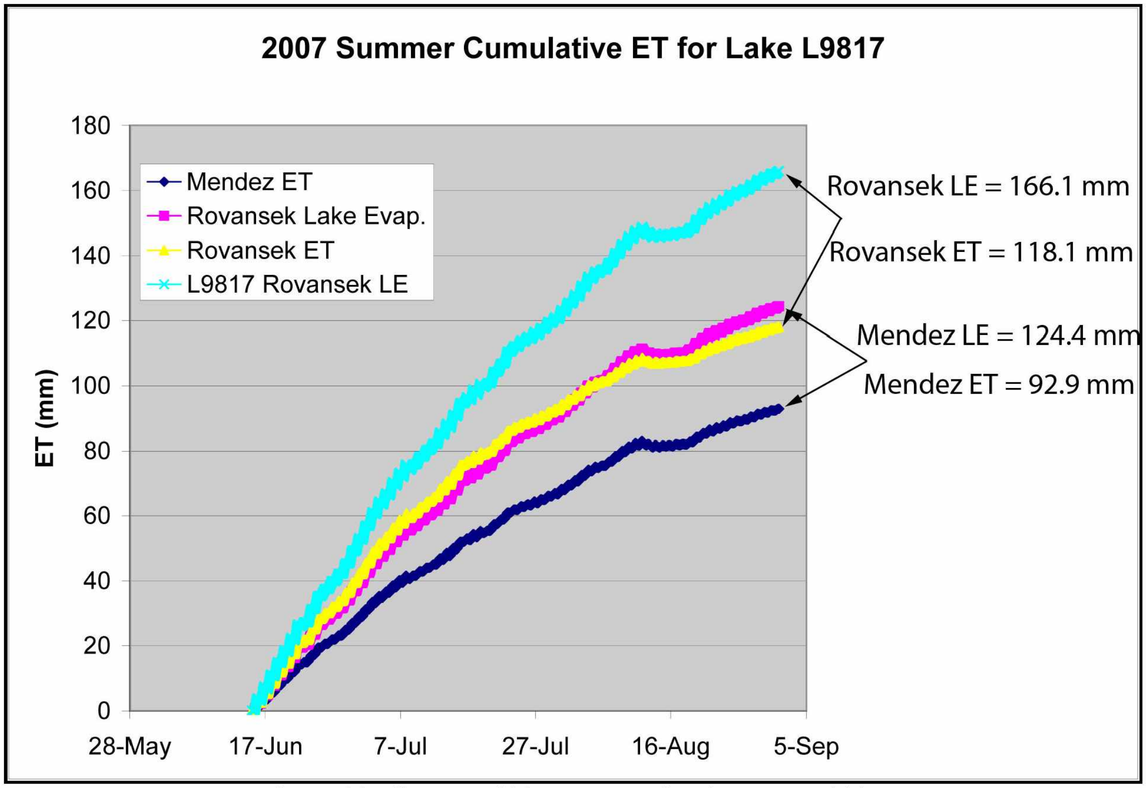


Figure 31 - Summer 2007 Evaporation for Lake L9817.

Water Use

Lake L9312 provides freshwater to the Alpine facility, and is pumped year round. All other lakes analyzed in the study were only pumped for winter ice road construction. For the 2006-2007 water year (Oct. – Sept.) 15.05 million gallons were withdrawn from Lake L9312. From October 2007 – May 2008, 10.26 million gallons were withdrawn from L9312.

Lake L9817 was not pumped during the winter of 2006-2007, but was pumped heavily during the winter of 2007-2008. For the 2006-2007 water year, no water was withdrawn from Lake L9817. From October 2007 – May 2008, 10.56 million gallons were withdrawn from the lake.

Potential Recharge

The potential recharge tool was used to produce results for Lakes L9312 and L9817. The actual output from the tool can be seen in Appendix A. Table 7 and Table 8 show the final inputs for the annual and seasonal potential recharge calculations in a more condensed format. Table 9 shows the corresponding water levels at the beginning and end of the calculated time periods.

Table 7 - Annual Potential recharge calculation for 2006-2007 water year.

Lake Name	LA (km^2)	WSA (km^2)	Rain (mm)	SWE (mm)	ET (mm)	LE (mm)	PR (MG)	Excess/ Deficit (MG)
L9312	0.50	1.03	22.60	117.20	89.60	119.80	9.67	-5.38
L9817	0.50	1.33	27.90	85.10	92.90	124.40	2.90	2.90

Table 8 – Seasonal Potential recharge calculations for 2007-2008 winter (Oct. – May)

Lake Name	LA (km^2)	WSA (km^2)	Rain (mm)	SWE (mm)	ET (mm)	LE (mm)	PR (MG)	Excess/ Deficit (MG)
L9312	0.50	1.03	-	118.8	-	-	32.33	22.08
L9817	0.50	1.33	-	105.3	-	-	37.00	26.44

Table 9 - Water levels for Lakes L9312 and L9817

Lake Name	October 2006 Water Level (fasl)	September 2007 Water Level (fasl)	October 2008 Water Level (fasl)	May 2008 Water Level (fasl)
L9312	7.70’	7.34’	7.33’	7.48’
L9817	Assumed Full	Observed Outflow (Full)	Slightly Overfull	52.90’ (assumed full)

For the annual potential recharge calculation, the overall deficit for Lake L9312 (-5.38 MG) was well represented by the corresponding water level drop (-0.36’). Exact water levels were not available for Lake L9817 for the specified start and end dates, yet the excess of 2.90 MG was also well represented by the observations of full recharge during this time period.

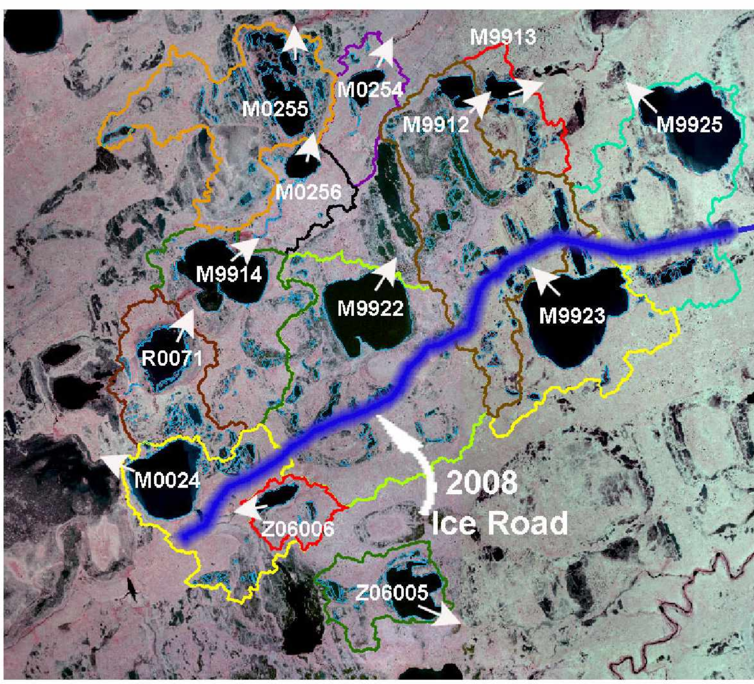
Seasonal potential recharge calculations for the 2007-2008 winter also matched corresponding water levels for Lakes L9312 and L9817. The excess for Lake L9817 of 22.08 MG was represented in the 0.15’ water level rise, although it appears that with this much potential recharge the water level should have risen more. At Lake L9817 the excess in the amount of 26.44 was seen as the Lake was fully recharged, although it was not overfull by as much as the tool predicts. These results do not incorporate appropriate storage deficits in the tundra that must be filled by some of the snowmelt and initial summer precipitation. With the dry 2007 summer, a parched tundra may have taken a large portion of the SWE, keeping a large portion of the snowmelt from reaching the lake. Knowing the tundra storage conditions going into freeze-up proves to be an important input, and is a current limitation of the potential recharge tool.

<u>2008 Ice Road Lakes</u>

A similar approach of calculating potential recharge was carried out for the 2008 ice road lakes. Not as much data are available at these lakes, so the determination of what data were most appropriate will be discussed throughout the process. The annual water balance was carried for the time period of June 2007 – May 2008.

Watershed Delineation

Watersheds were delineated for the Rendezvous areas (Figure 32). This area contained the most study lakes.



Lake Name	Lake Area (km^2)	Watershed Area (km^2)
Z06005	0.38	1.24
Z06006	0.11	0.64
M0024	0.71	2.43
R0071	0.43	1.76
M9914	0.68	2.66
M0256	0.14	1.08
M0255	0.58	3.23
M9912	0.71	4.63
M0254	0.15	1.04
M9913	0.18	1.00
M9922	1.00	5.41
M9923	1.12	2.45
M9925	1.02	3.80

Figure 32 - Rendezvous Area final watershed areas and outflow directions (Scale: 1 cm = 667 m).

The resulting watershed areas in the Rendezvous area ranged from 0.64 km^2 to 5.41 km^2. Lake area typically took up between 15 – 30 % of the total watershed area, much lower than the other study areas. Lakes Z06005, Z06006, R0071, M0254, M9922, M9923, and M9925 are isolated and receive no inflow from adjacent study lake watershed areas. The remaining lakes are connected through stream networks. These observations were taken into account when inputting data into the potential recharge tool.

Snow Water Equivalent

Additional snow data were gathered during the 2008 breakup trip. During March snow courses were conducted along the 2008 ice road at two mile intervals. The snow courses at Lake L9817 and Lake L9312 were also included when looking at general trends of snow distribution. The results of these snow courses were broken into the three areas for watershed delineation and averaged (Figure 33). From the averages it can be seen that the L9312 and L9817 areas have similar SWE values, while the Rendezvous area is significantly higher.

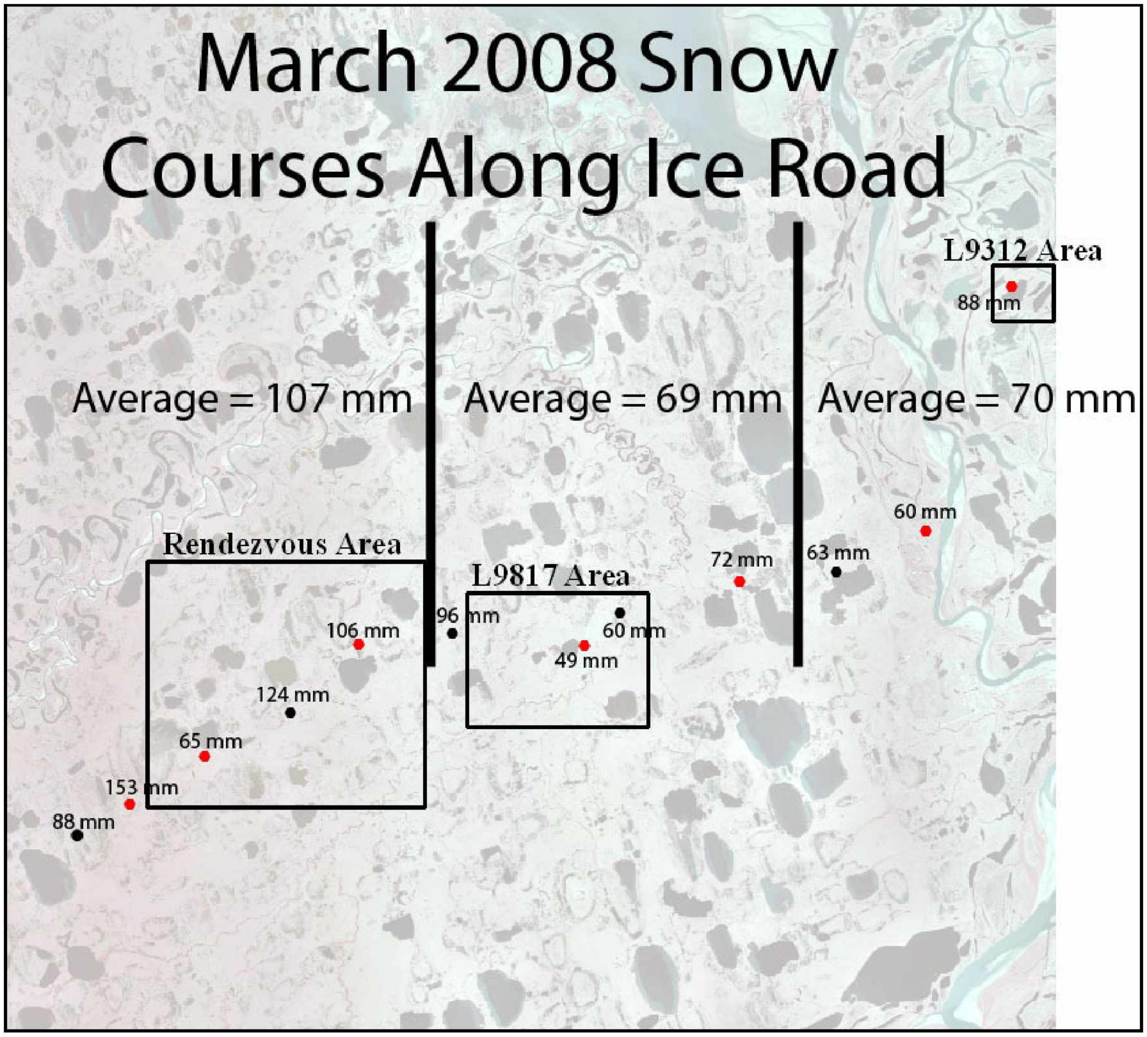


Figure 33 – 2008 Ice Road snow course results for March 2008 (Scale: 1 cm = 2.4 km)

Six of the snow courses were repeated during mid May prior to snowmelt (Figure 34). To recognize trends, the snow grids were also added to this analysis. Since the snow grids contain more measurements, they were double weighted in the averaging process. A similar trend was seen as in the March snow courses. The L9312 and L9817 areas were very similar, whereas the Rendezvous area had significantly more snow. All of the snow courses were conducted on the tundra. In the Alaskan Arctic Coastal Plain, the tundra generally has a higher SWE average than lake surfaces (Sturm and Liston, 2003).

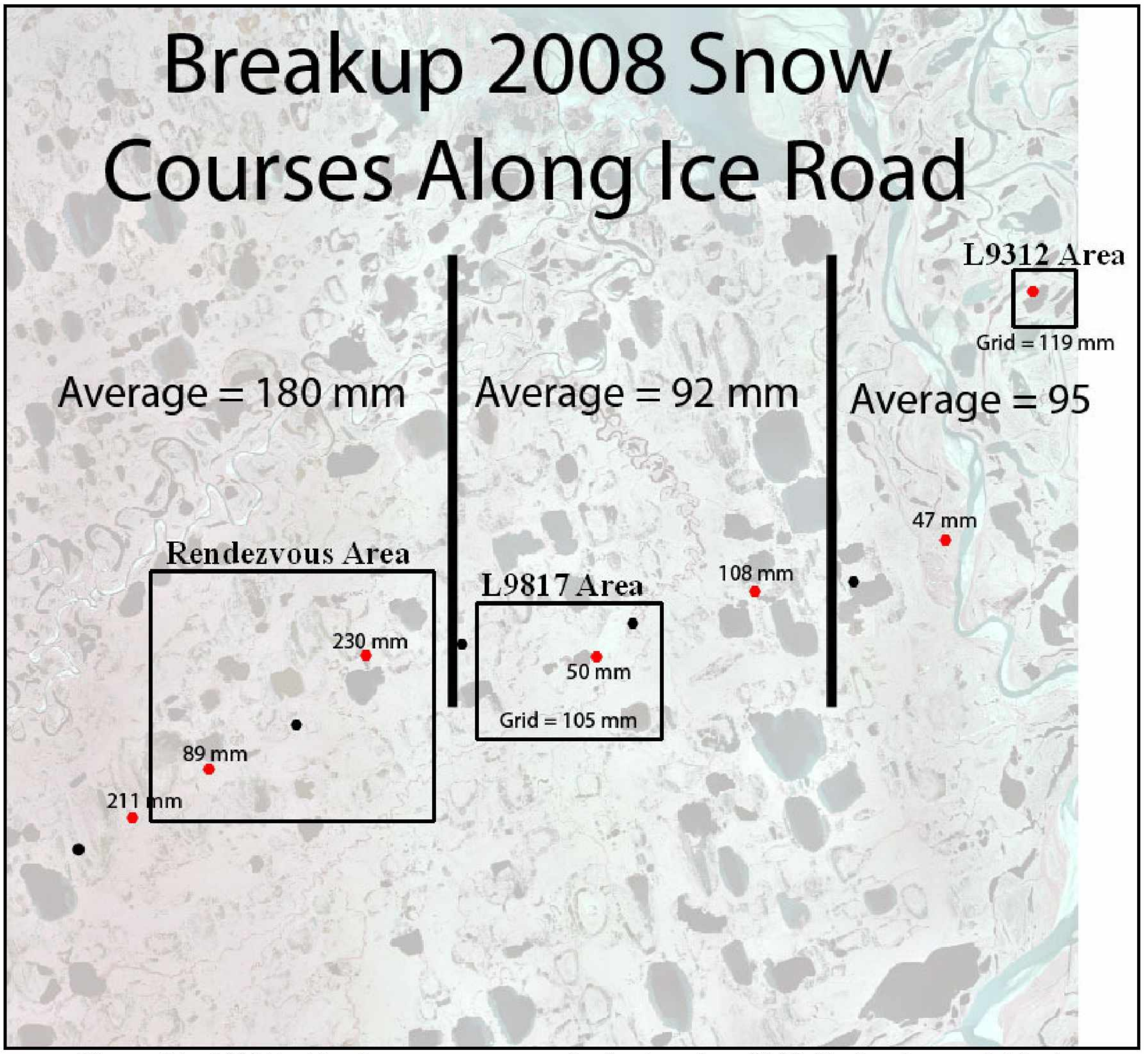


Figure 34 - 2008 Ice Road snow course results for breakup 2008 (Scale: 1 cm = 2.4 km)

An exact SWE value for the 2008 ice road area was not directly calculated, and therefore was estimated for the potential recharge calculation. As seen in the results, the average from the three snow courses in the region was approximately 180 mm.

Considering that all of these snow courses were conducted on the tundra, an area where SWE is typically overestimated by this type of analysis, this value will be conservatively downscaled to 150 mm for the potential recharge calculation.

Rainfall

Rainfall for the 2008 ice road study lakes was obtained from the L9817 weather station, as shown in the Theissen Polygon map for rainfall (Figure 24). Final input values can be seen in Table 10.

Evaporation and Evapotranspiration

Evaporation and Evapotranspiration will be obtained from the L9817 weather station, as shown in the Theissen Polygon map for ET (Figure 25). Final input values can be seen in Table 10.

Water Use

Only two of the study lakes in this region were pumped during the 2007-2008 winter months. A total of 10.42 MG was used from Lake M0024, while 4.79 MG was withdrawn from Lake M9923 during the given period of analysis.

Potential Recharge

Potential recharge was calculated for the period from June 2007 – May 2008 using the inputs determined by the described methods and results (Table 10).

Table 10 - Final Parameters and Potential Recharge Calculation for 2008 Ice Road study lakes.

Lake Name	LA (km^2)	WSA (km^2)	Rain (mm)	SWE (mm)	ET (mm)	LE (mm)	PR (MG)	Excess/ Deficit (MG)
Z06005	0.38	1.24	27.90	150.00	92.90	124.40	24.68	-
Z06006	0.11	0.64	27.90	150.00	92.90	124.40	13.46	-
*M0024	0.71	2.43	27.90	150.00	92.90	124.40	48.66	38.24
R0071	0.43	1.76	27.90	150.00	92.90	124.40	35.94	-
M9914	0.68	2.66	27.90	150.00	92.90	124.40	54.07	-
M0256	0.14	1.08	27.90	150.00	92.90	124.40	23.09	-
M0255	0.58	3.23	27.90	150.00	92.90	124.40	67.70	-
M9912	0.71	4.63	27.90	150.00	92.90	124.40	98.06	-
M0254	0.15	1.04	27.90	150.00	92.90	124.40	22.10	-
M9913	0.18	1.00	27.90	150.00	92.90	124.40	20.96	-
M9922	1.00	5.41	27.90	150.00	92.90	124.40	113.16	-
*M9923	1.12	2.45	27.90	150.00	92.90	124.40	45.69	40.90
M9925	1.02	3.80	27.90	150.00	92.90	124.40	76.84	-

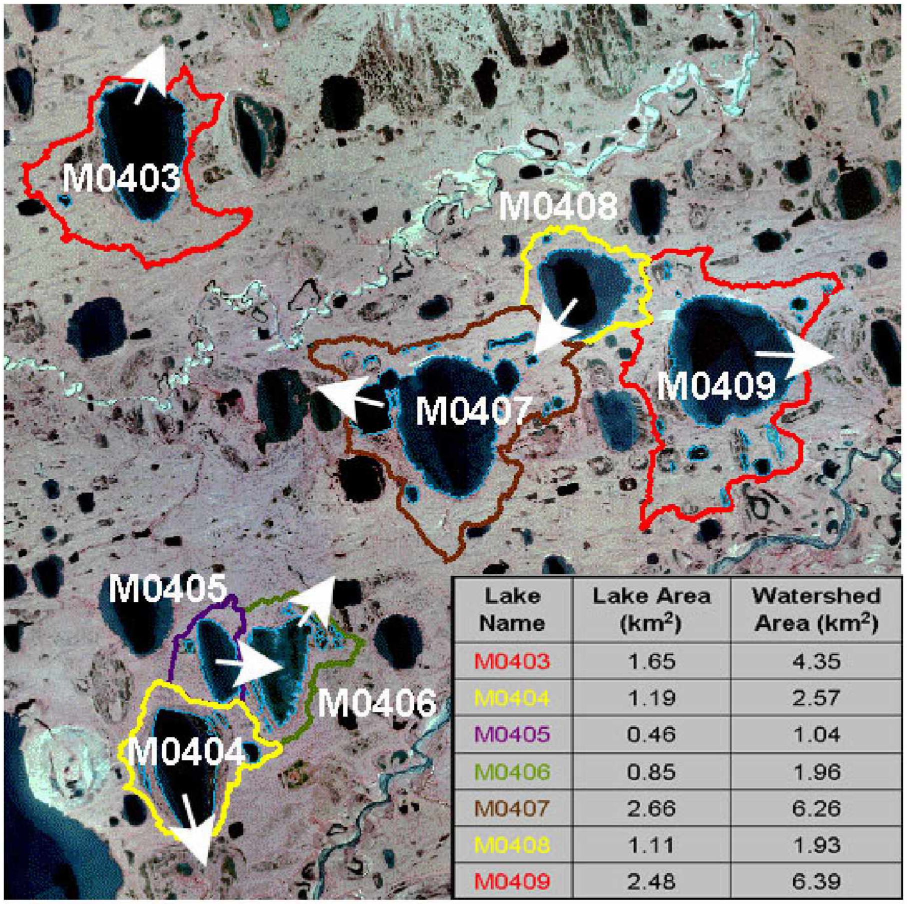
The results indicate that all of the lakes have a positive value for potential recharge, indicating that the lakes will fully recharge if the assumption of an initial full lake is made. The only two lakes that were pumped during the time period showed a large excess in available water. In this area, six lakes were visited during breakup 2008. Photographs were taken to document recharge in the area. These aerial site visits showed that all six lakes were fully recharged and overflowing by early June (Photographs shown in Appendix C). This validates the potential recharge calculations. Two of these six photographed lakes were pumped (M0024 and M9923). The potential recharge calculation for these lakes showed a great amount of excess recharge, that is also validated by the aerially photos.

NPRA Test Lakes

The NPRA Test Lakes are the study lakes that have the least known information. The potential recharge tool will be used to calculate recharge estimates for these lakes with the available information during the time period of June 2007 – May 2008.

Watershed Delineation

The two areas represented for the NPRA Test Lakes are the UAFWS3 Area and the Fish Creek Area. Since the DEM covered these areas, Rivertools was used to delineate watersheds for the chosen test lakes (Figure 35 and Figure 36). Site visits were not possible to these lakes to verify the Rivertools results.



Lake Name	Lake Area (km²)	Watershed Area (km²)
M0403	1.65	4.35
M0404	1.19	2.57
M0405	0.46	1.04
M0406	0.85	1.96
M0407	2.66	6.26
M0408	1.11	1.93
M0409	2.48	6.39

Figure 35 – UAFWS3 Area final watershed areas and outflow directions (Scale: 1 cm = 1.4 km)

The resulting watershed areas in the UAFWS3 area range from about 1 km^2 to 6.5 km^2. Lake area typically occupied between 35 – 45 % of the total watershed area, with the exception of M0408 which was higher at 58%. Lakes M0403, M0404, M0405, M0408 and M0409 appeared to be isolated receiving no inflow from adjacent watersheds. Lake M0406 appeared to receive overflow from the Lake M0405 watershed area. Lake M0407 appeared to receive overflow from the Lake M0408 watershed area. These observations were taken into account when inputting data into the potential recharge tool.

ArcMap was used to delineate the watershed areas for the UAFWS3 area in order to again validate the Rivertools' results (Table 11). The results showed that the resulting watershed areas never differed by more than 1%.

Table 11 - ArcMap watershed results vs. Rivertools' watershed results for UAFWS3 Area.

Lake Name	Rivertools Watershed Area (km^2)	ArcMap Watershed Area (km^2)	Percent Difference
M0403	4.350	4.372	0.51%
M0404	2.569	2.584	0.58%
M0405	1.038	1.046	0.77%
M0406	1.957	1.946	0.56%
M0407	6.264	6.263	0.02%
M0408	1.933	1.947	0.72%
M0409	6.388	6.418	0.47%

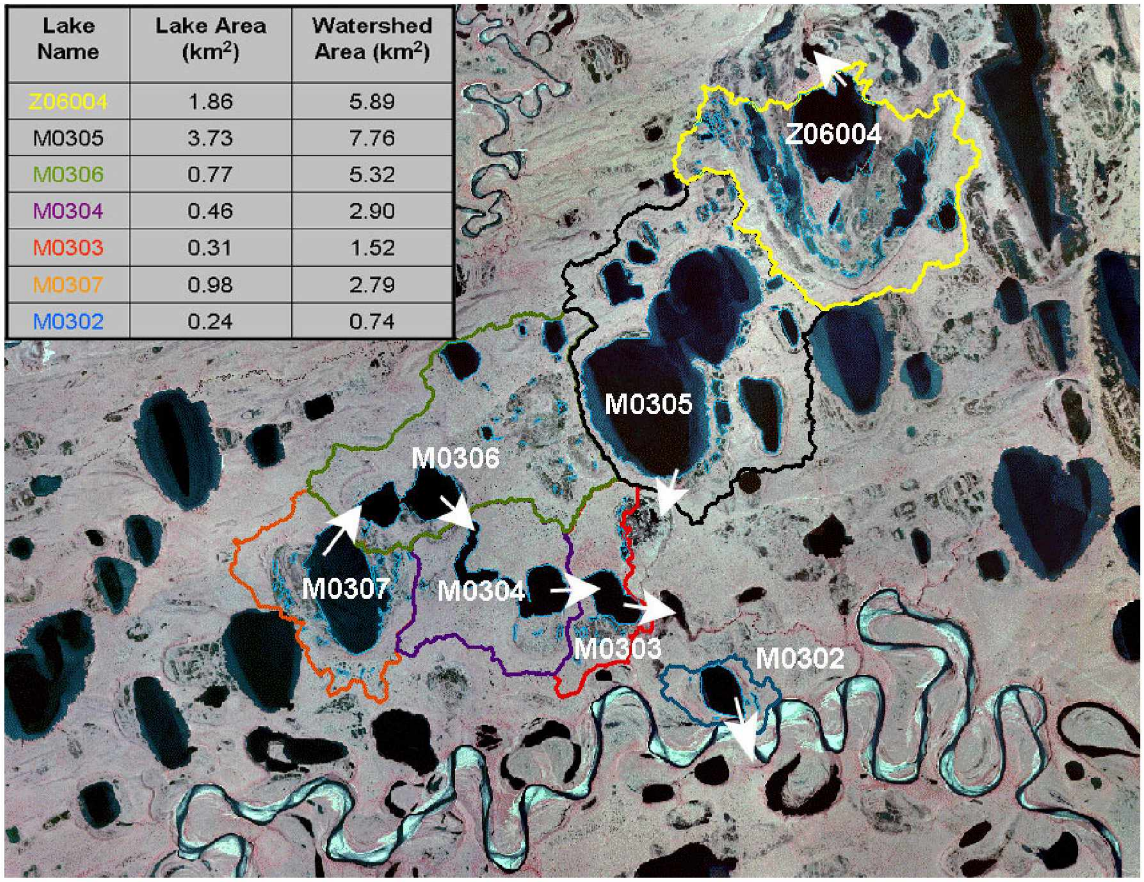


Figure 36 - Fish Creek Area final watershed areas and outflow directions (Scale: 1 cm = 1 km)

Watershed areas within the Fish Creek area range from 0.74 km^2 to almost 8 km^2. Lakes take up less of the watershed areas than in the UAFWS3 region, ranging from 15% to 50 %. This means there is generally more tundra area available for recharge from snowmelt and rainfall. Lakes Z06004, M0302, M0305 and M0307 appear to be isolated receiving no overflow from adjacent watersheds. However, it seems that M0307 could potentially receive overflow from the lake located directly to the west. Since this lake was not analyzed, information about the amount of overflow will not be calculated and therefore cannot be included in the potential recharge calculation for M0307. Lakes

M0306, M0304, and M0303 appear to be located along a flow path. The tundra stream was visible from the aerial image, and appropriate overflow volumes for these watersheds were taken into consideration in the potential recharge calculations.

Snow Water Equivalent

During the 2008 breakup trip it was observed that snowpack generally increased when moving west. This was attributed to two factors. First, the general wind direction in this region blows southwest. With the wind blows in this direction, snow may be redistributed from east areas towards west regions. Second is the increased topographic relief as moving westward, as seen in the DEM. With more changes in topography, the blowing snow would have more areas to accumulate.

Since no data were available for this region, it was conservatively assumed that the SWE in the area was the same as in the 2008 ice road study lake area. The end of winter SWE input for the potential recharge tool was chosen to be 150 mm for the given time period.

Rainfall

Rainfall for the NPRA Test lakes came from three weather stations. The UAFWS3 weather station showed the lowest total precipitation for the summer of 2007. This station was located the farthest west of all the stations. The graphs of the 2007 cumulative rainfall (Figure 37) show that a rainfall event may have occurred towards the eastern portion of the study area in late June, missing the western area around UAFWS3.

With such a low rainfall year, this greatly impacted rainfall estimates for the western part of the study region.

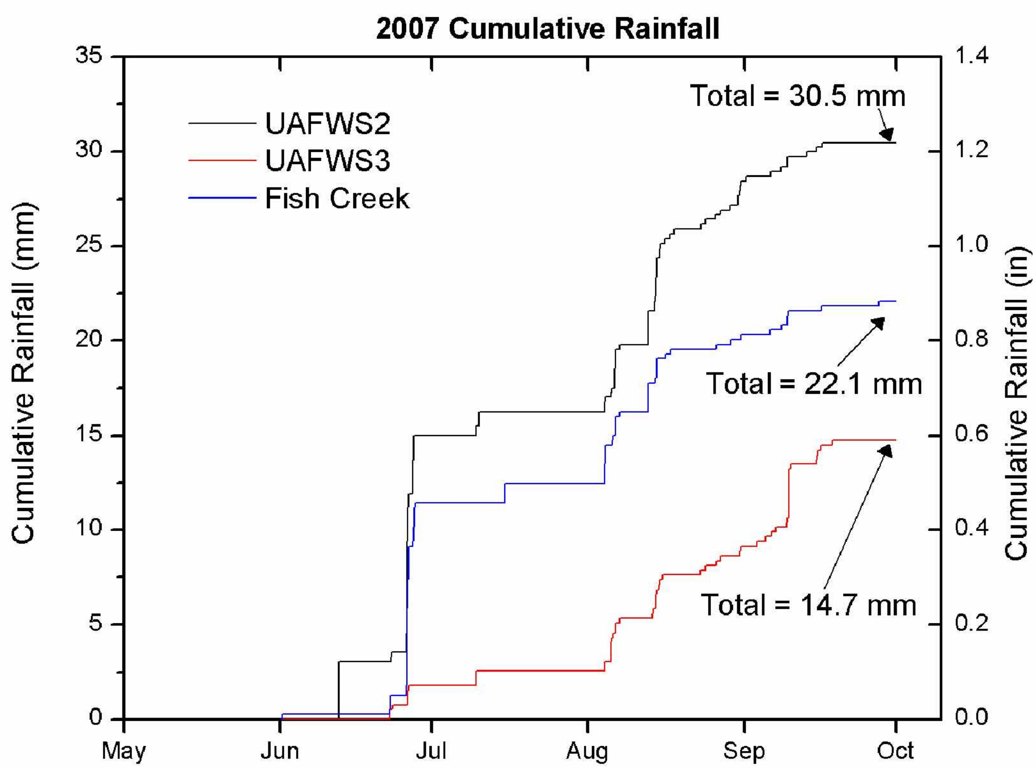


Figure 37 – 2007 Rainfall for UAFWS2, UAFWS3, and Fish Creek

Rainfall values for the lakes in the Fish Creek area were split between the Fish Creek and UAFWS2 weather station, while all of the UAFWS3 area will use the UAFWS3 weather station (Figure 24).

Evaporation and Evapotranspiration

Evaporation and evapotranspiration estimates for the NPRA study lake area all came from the UAFWS3 Weather Station (Figure 38). ET calculations for this region were substantially higher than in the other regions (Figure 38). The Mendez alpha values were applied in the potential recharge calculations.

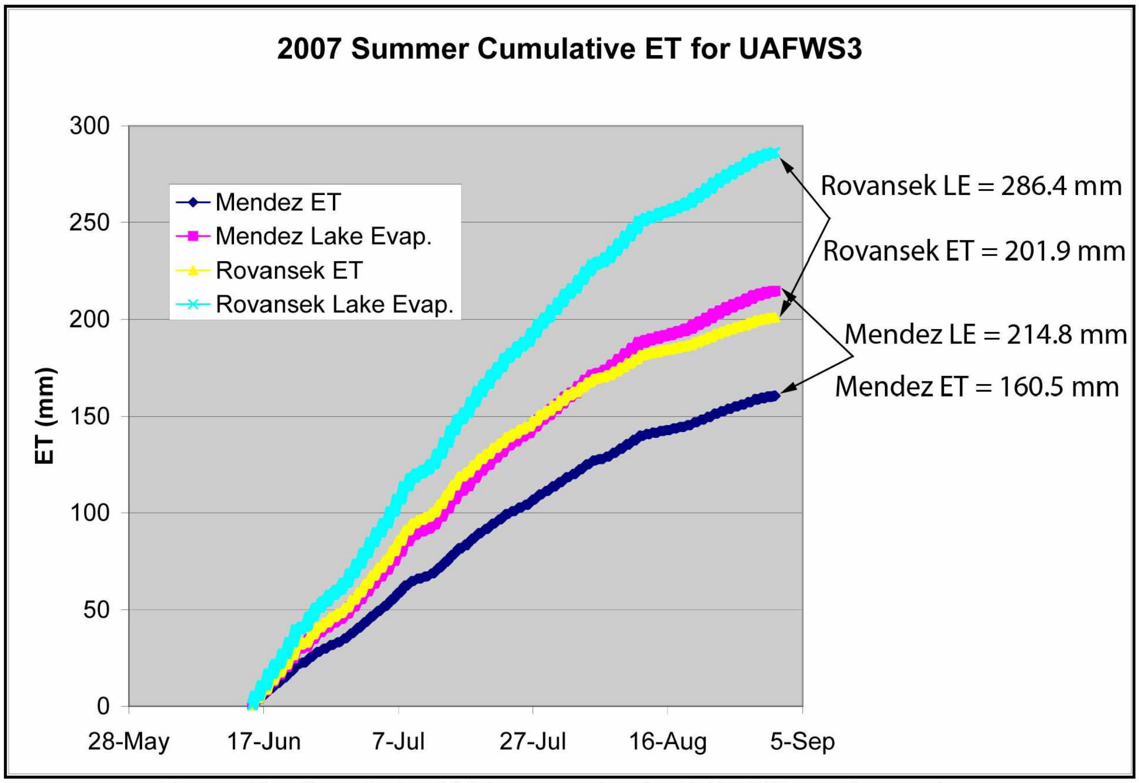


Figure 38 – Cumulative 2007 evaporation for UAFWS3 weather station.

Water Use

None of these lakes were pumped during the period of analysis.

Potential Recharge

Potential recharge was calculated for the period from June 2007 – May 2008 using the inputs determined by the described methods and results (Table 12).

Table 12 - Final Parameters and Potential Recharge Calculation for NPRA Test Lakes.

Lake Name	LA (km^2)	WSA (km^2)	Rain (mm)	SWE (mm)	ET (mm)	LE (mm)	PR (MG)
Z06004	1.86	5.89	22.1	150	160.5	214.8	-8.63
M0305	3.73	7.76	22.1	150	160.5	214.8	-29.72
M0306	0.77	5.32	30.5	150	160.5	214.8	17.06
M0304	0.46	2.9	30.5	150	160.5	214.8	8.72
M0303	0.31	1.52	30.5	150	160.5	214.8	3.58
M0307	0.98	2.79	30.5	150	160.5	214.8	0.68
M0302	0.24	0.74	30.5	150	160.5	214.8	0.46
M0403	1.65	4.35	14.7	150	160.5	214.8	-18.84
M0404	1.19	2.57	14.7	150	160.5	214.8	-14.21
M0405	0.46	1.04	14.7	150	160.5	214.8	-5.44
M0406	0.85	1.96	14.7	150	160.5	214.8	-10.01
M0407	2.66	6.26	14.7	150	160.5	214.8	-31.21
M0408	1.11	1.93	14.7	150	160.5	214.8	-13.78
M0409	2.48	6.39	14.7	150	160.5	214.8	-28.48

Potential recharge calculations for this area range from -28 MG to 17 MG. This was the only region of all the study lakes that showed negative potential recharge calculations for the period of analysis. Unfortunately, site visits were not taken to these lakes during breakup 2008. Station maintenance was conducted at the UAFWS3 and Fish Creek weather stations before snowmelt. A general observation was made that most of the lakes in the region appeared to be notably low. The lakes were still covered with ice at this point, but the top of ice appeared to be below the shoreline for many of the lakes, whereas this was not the case at the other study lakes. This observation would be confirmed by the results of the extremely low rainfall totals combined with high ET values for the summer of 2007 in the western region of the study area.

Conclusions and Recommendations

Potential Recharge Estimates on the North Slope

Having analyzed three different regions with different levels of accuracy provides good incite to the varying degrees of certainty of potential recharge estimates. The recharge estimates of the NPRA Test Lakes region do not carry the same amount accuracy that the estimates of Lake L9312 and Lake L9817 carry. If Lake L9312 had been analyzed at the same accuracy scale as the NPRA Test Lakes, the presence of the groundwater interaction would not have been seen, producing an underestimation in recharge. Conversely, recharge could just as easily be overestimated due to a scarcity of available data. Extrapolation of weather parameters over such a large region admittedly presents limitations. With improved data and a better understanding of the region, the accuracy of these estimates will only improve. However at the currently level of data availability, and with the agreement of recharge estimations and field results, it can be concluded that the recharge estimates in this study are an improvement to current water permitting practices and estimate recharge fairly well.

The results from this study show that all pumped lakes analyzed fully recharged for the given period of analysis. With such a short period of analysis, it is difficult to absolutely conclude that current water use practices have no adverse impact on physical recharge. For example, it would be possible during a dry water year for a lake to not recharge due to pumping. Yet results from other studies (Lilly et. al., 1998, Hinzman et. al., 2006) have shown that spring snowmelt in this region far exceeds surface storage resulting in lakes being fully recharged by early summer. With the current conservative water use permitting, it seems unlikely that a lake would fail to fully recharge for several consecutive years. It is concluded that water removal from the selected study lakes did not adversely affect the recharge of the water bodies during the study period.

There is much room for improved water use practices on the North Slope. Parameters such as “lake-full elevation” or “full recharge” are not well defined and across the board measurements are not established. Other hydrologic terms such as "watershed area" are often misused causing confusion among water users. While the lack of data present one problem in this region, the lack of knowledge creates another. Both of these problems need to be addressed to improve management practices.

Watershed Delineation

Digital watershed delineation using remote sensing techniques has the potential to greatly enhance our understanding of hydrologic processes on the Alaskan Arctic Coastal Plain. The methods are not flawless, as seen in the final watershed area of Lake L9312, yet they did prove fairly accurate in the estimations of surface water outlets and flowpaths. Difficulties with digital watershed delineation arise from the low variability in relief combined with the wetlands environment. More thorough studies on the effects that these two issues create for remotely sensed data accuracy would be useful. However with the field verification of the watershed areas for L9312 and L9817, this study indicates that methods of digital watershed delineation for surface flow are reasonable.

Watershed areas are generally static and do not change significantly over time. It is recommended that watershed areas be delineated for all permitted lakes in the future. The process could be done in a somewhat automated scheme with the appropriate DEM data. While the watershed area data may not be used in the immediate future, it can be archived in the lake records making it more likely for lake specific parameters to be used in future permitting efforts. Incorporating watershed areas into the lake permits would be a good step towards integrating hydrologic terms into water-use management.

Meteorological Data

Of the meteorological data looked at in this study, SWE was the most challenging to estimate. Obtaining an accurate estimation of SWE over an entire basin was difficult due to the changing spatial distribution across the North Slope. Determining an accurate value for SWE is very important in the calculation of potential recharge. For management to utilize the potential recharge tool, it is recommended to obtain accurate end of winter SWE values. Under or over estimation of this term can greatly impact the predicted amount of potential recharge.

Evapotranspiration estimates were also quite variable in the study. The Priestly-Taylor method was fairly easy to use, however the alpha term created a large amount of uncertainty in the calculations. A better understanding of this alpha term for the Alaskan Arctic Coastal Plain would be beneficial in such estimates.

Potential Recharge Tool

The potential recharge tool was able to quickly determine recharge for the selected study lakes. As discussed previously, these recharge estimates matched field observations well. Like any hydrologic model, the level of accuracy is dependent on the accuracy of the inputs. The tool was able to more accurately predict recharge for lakes like L9312 and L9817 due to increased accuracy. Initial results and past data for these lakes allowed for calibration of input parameters.

One drawback of using this tool is the amount of preprocessing of data required. It is not meant to be a standalone tool as it requires most of the inputs to be calculated with other methods. Proper documentation of applied methodologies is important each time the tool is used to give credibility to the results.

At current level of data availability, applying the above mentioned hydrologic methods to water-use practices on the North Slope is highly recommended. The results of this study show that applying basic parameters, such as watershed areas and weather inputs, can yield results that are directly applicable to water management. The potential recharge tool is easy to use and provides an increased level of organization for water permitting and water-use applications. The tool is not meant to perform like other hydrologic models that require a large amount of inputs currently unavailable in this region. Instead, the tool is quickly and easily applicable for the North Slope where data is scarce. Using such a tool can only improve water management practices in the future.

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Appendix A – Potential Recharge Tool Output for Study Lakes

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0256		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.24439	151.60801	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	1.08	km2
Lake Surface Area(s):	0.14	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M0256	
Notes:		
		Units
Watershed to Lake Area Ratio:	7.71	none
Annual Potential Recharge (PR):	23.08	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0302		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	3.27	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.25719	152.17616	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	0.74	km2
Lake Surface Area(s):	0.24	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	30.50	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**M0302**	
Notes:		
		Units
Watershed to Lake Area Ratio:	3.08	none
Annual Potential Recharge (PR):	0.47	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-2.80	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0303		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	1.46	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.26706	152.20824	NAD83	

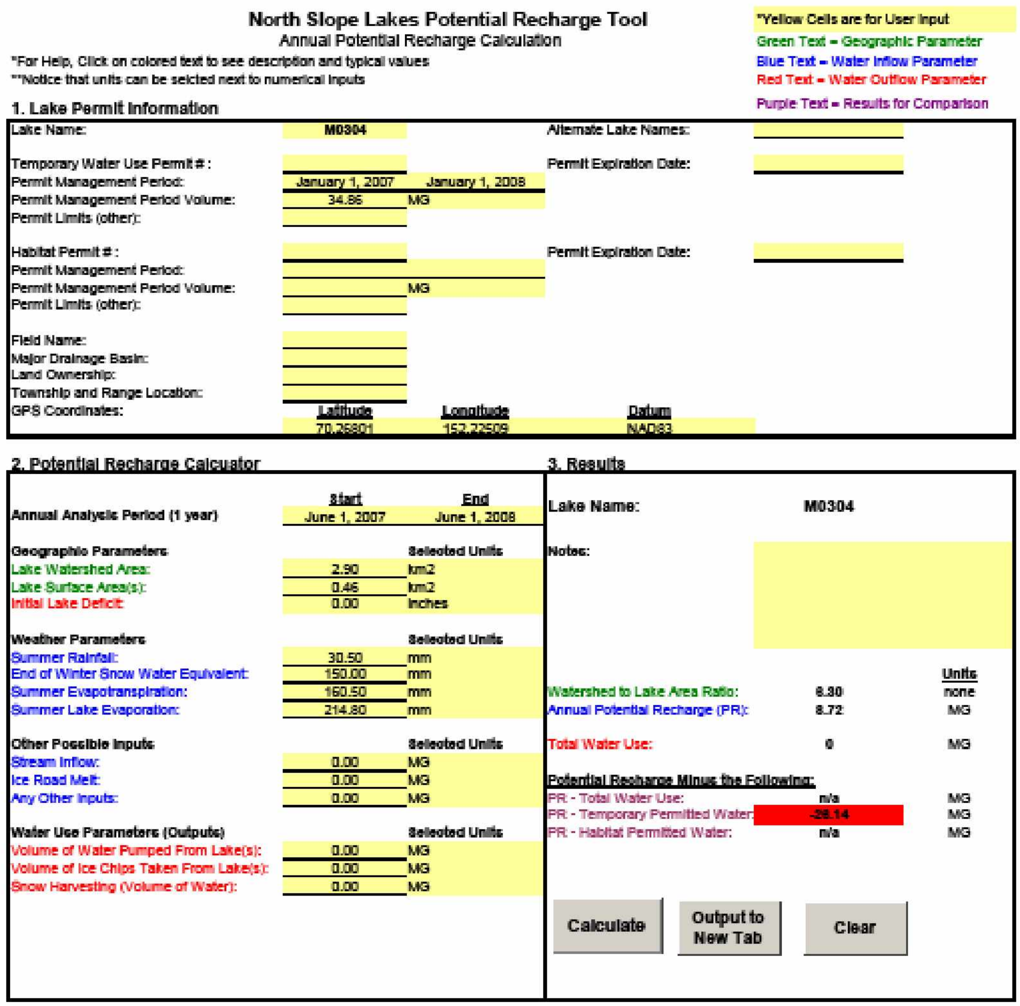
2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	1.52	km2
Lake Surface Area(s):	0.31	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	30.50	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**M0303**	
Notes:		
		Units
Watershed to Lake Area Ratio:	4.90	none
Annual Potential Recharge (PR):	3.68	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	2.12	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear


North Slope Lakes Potential Recharge Tool
Annual Potential Recharge Calculation
*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs
*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison
1. Lake Permit Information
Lake Name:
M0304
Alternate Lake Names:
Temporary Water Use Permit # :
Permit Expiration Date:
Permit Management Period:
January 1, 2007
January 1, 2008
Permit Management Period Volume:
34.86
MG
Permit Limits (other):
Habitat Permit # :
Permit Expiration Date:
Permit Management Period:
Permit Management Period Volume:
MG
Permit Limits (other):
Field Name:
Major Drainage Basin:
Land Ownership:
Township and Range Location:
GPS Coordinates:
Latitude
Longitude
Datum
70.26801
152.22509
NAD83
2. Potential Recharge Calculator
Start
End
Annual Analysis Period (1 year)
June 1, 2007
June 1, 2008
Geographic Parameters
Selected Units
Lake Watershed Area:
2.90
km2
Lake Surface Area(s):
0.46
km2
Initial Lake Deficit:
0.00
inches
Weather Parameters
Selected Units
Summer Rainfall:
30.50
mm
End of Winter Snow Water Equivalent:
150.00
mm
Summer Evapotranspiration:
160.50
mm
Summer Lake Evaporation:
214.80
mm
Other Possible Inputs
Selected Units
Stream Inflow:
0.00
MG
Ice Road Melt:
0.00
MG
Any Other Inputs:
0.00
MG
Water Use Parameters (Outputs)
Selected Units
Volume of Water Pumped From Lake(s):
0.00
MG
Volume of Ice Chips Taken From Lake(s):
0.00
MG
Snow Harvesting (Volume of Water):
0.00
MG
3. Results
Lake Name:
M0304
Notes:
Units
Watershed to Lake Area Ratio:
6.30
none
Annual Potential Recharge (PR):
8.72
MG
Total Water Use:
0
MG
Potential Recharge Minus the Following:
PR - Total Water Use:
n/a
MG
PR - Temporary Permitted Water:
-26.14
MG
PR - Habitat Permitted Water:
n/a
MG
Calculate
Output to New Tab
Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0305		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	28.88	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.28695	152.19686	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	7.76	km2
Lake Surface Area(s):	3.73	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	22.10	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M0305	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.08	none
Annual Potential Recharge (PR):	-29.73	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-58.61	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0306		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	25.5	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.27827	152.25843	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	5.32	km2
Lake Surface Area(s):	0.77	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	30.50	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**M0306**	
Notes:		
		Units
Watershed to Lake Area Ratio:	6.91	none
Annual Potential Recharge (PR):	17.06	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-8.44	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0307		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.26838	152.28894	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	2.79	km2
Lake Surface Area(s):	0.98	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		Selected Units
Summer Rainfall:	30.50	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**M0307**	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.86	none
Annual Potential Recharge (PR):	0.88	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0403		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.38960	153.52083	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	4.35	km2
Lake Surface Area(s):	1.65	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	14.70	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

		Units
Lake Name:	**M0403**	
Notes:		
Watershed to Lake Area Ratio:	2.84	none
Annual Potential Recharge (PR):	-18.84	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0404		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	15.88	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.31562	153.50552	NAD83	

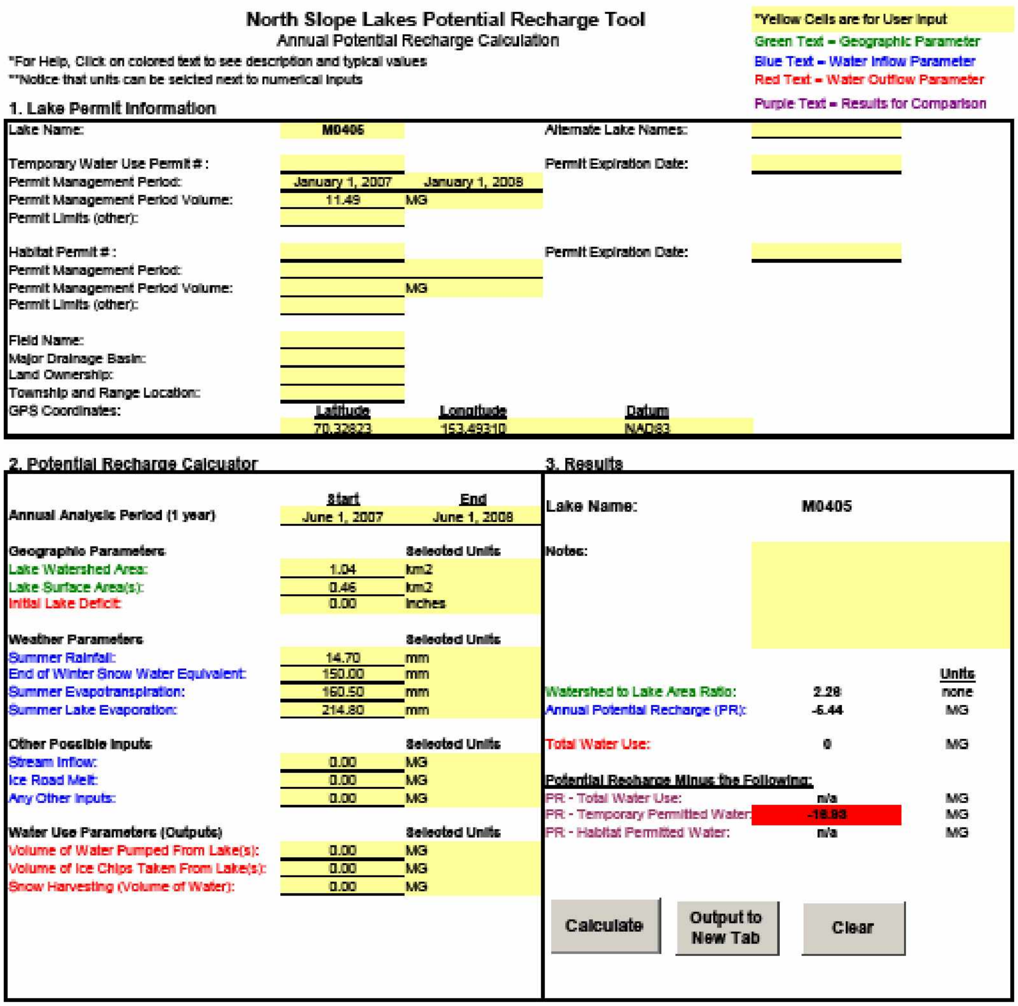
2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	2.57	km2
Lake Surface Area(s):	1.19	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	14.70	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M0404	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.16	none
Annual Potential Recharge (PR):	-14.22	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-30.10	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear



North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0405		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	11.49	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.32823	153.49310	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	1.04	km2
Lake Surface Area(s):	0.46	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	14.70	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M0405	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.28	none
Annual Potential Recharge (PR):	-5.44	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-16.93	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0406		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	2.19	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.32802	153.47480	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	1.96	km2
Lake Surface Area(s):	0.85	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	14.70	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**M0406**	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.31	none
Annual Potential Recharge (PR):	-10.02	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-12.21	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0407		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	74.03	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.35703	153.41198	NAD83	

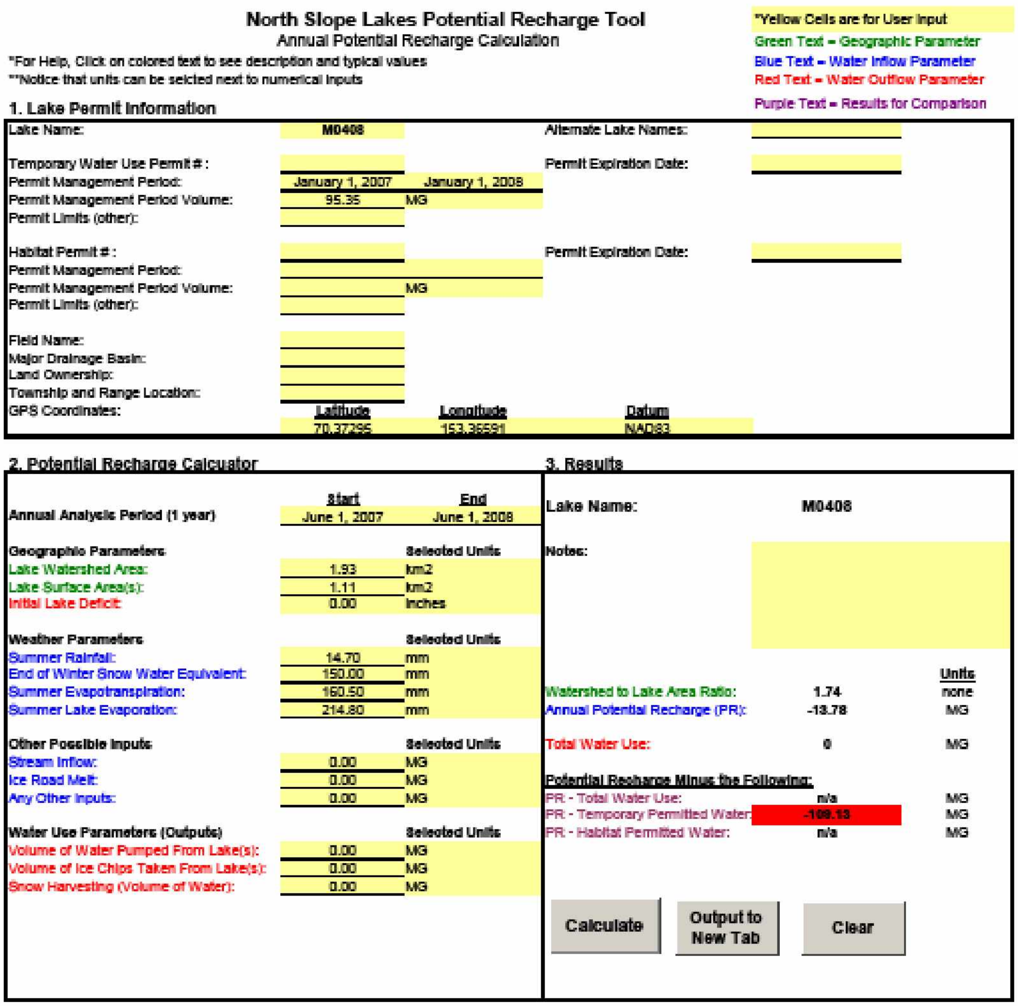
2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	6.26	km2
Lake Surface Area(s):	2.66	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		Selected Units
Summer Rainfall:	14.70	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M0407	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.36	none
Annual Potential Recharge (PR):	-31.21	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-105.24	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear



North Slope Lakes Potential Recharge Tool
Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0408		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	95.35	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.37295	153.36591	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	1.93	km2
Lake Surface Area(s):	1.11	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		Selected Units
Summer Rainfall:	14.70	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name: M0408

Notes:

		Units
Watershed to Lake Area Ratio:	1.74	none
Annual Potential Recharge (PR):	-13.78	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-109.13	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0409		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	13.36	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	**Latitude**	**Longitude**	**Datum**	
	70.35423	153.31113	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008

Geographic Parameters		**Selected Units**
Lake Watershed Area:	6.39	km2
Lake Surface Area(s):	2.48	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	14.70	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

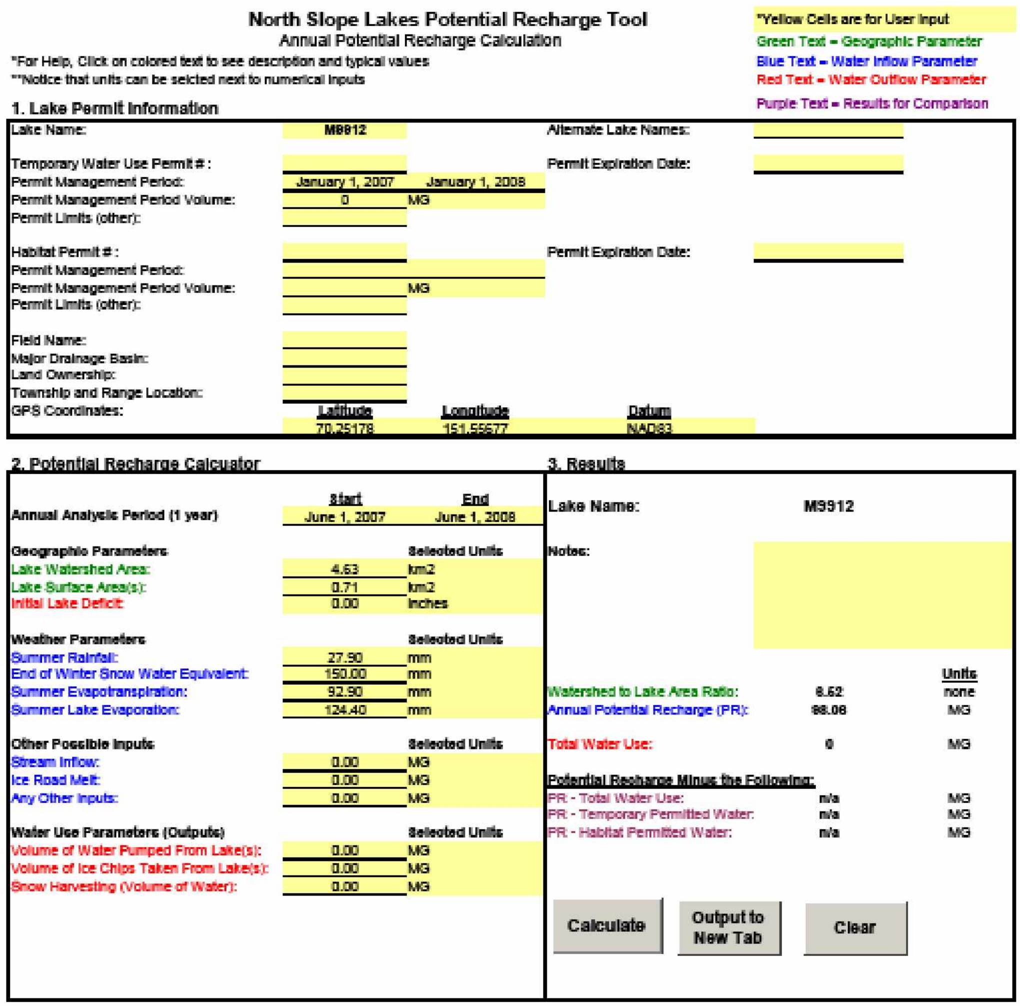
3. Results

Lake Name: M0409

Notes:

		Units
Watershed to Lake Area Ratio:	2.58	none
Annual Potential Recharge (PR):	-28.48	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-41.84	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear



North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M9912		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.25178	151.55677	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	4.63	km2
Lake Surface Area(s):	0.71	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		Selected Units
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M9912	
Notes:		
		Units
Watershed to Lake Area Ratio:	6.52	none
Annual Potential Recharge (PR):	98.06	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M9913		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.25157	151.54264	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	1.00	km2
Lake Surface Area(s):	0.18	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		Selected Units
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M9913	
Notes:		
		Units
Watershed to Lake Area Ratio:	5.58	none
Annual Potential Recharge (PR):	20.98	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M9914		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	41.02	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70 14.00	150 37.84	NAD83	

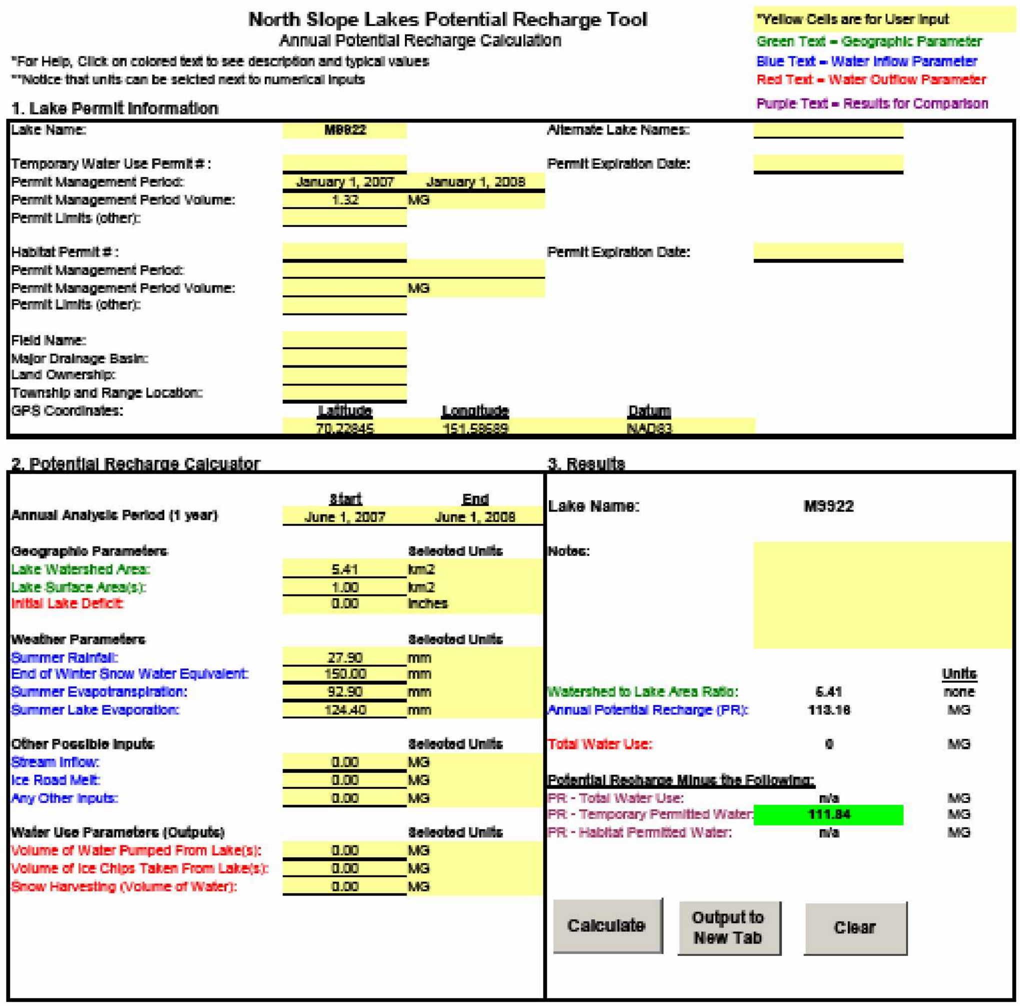
2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	2.66	km2
Lake Surface Area(s):	0.68	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

		Units
Lake Name:	M9914	
Notes:		
Watershed to Lake Area Ratio:	3.91	none
Annual Potential Recharge (PR):	64.07	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	13.06	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear



North Slope Lakes Potential Recharge Tool
Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M9922		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	1.32	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.22845	151.58689	NAD83	

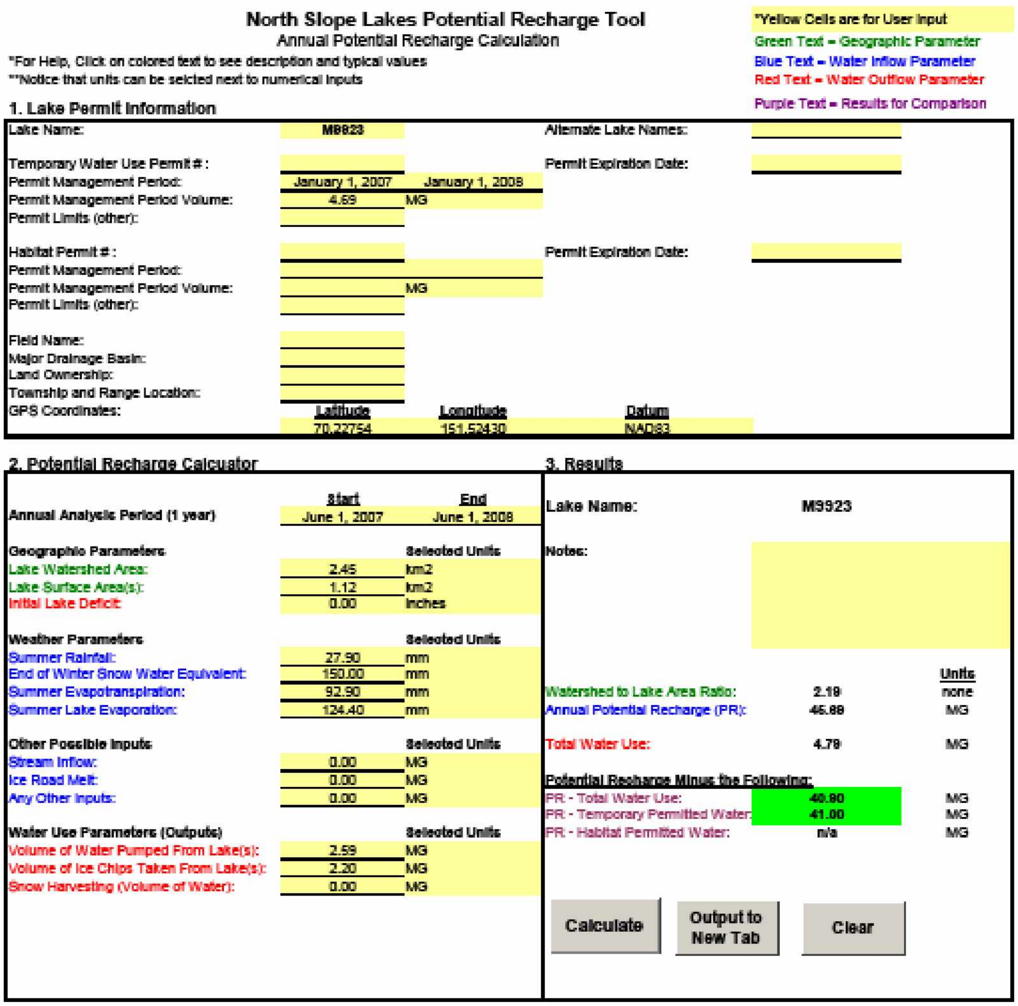
2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	5.41	km2
Lake Surface Area(s):	1.00	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		Selected Units
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M9922	
Notes:		
		Units
Watershed to Lake Area Ratio:	5.41	none
Annual Potential Recharge (PR):	113.16	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	111.84	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate
Output to New Tab
Clear



North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M9923		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	4.69	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.22754	151.52430	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	2.45	km2
Lake Surface Area(s):	1.12	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	2.59	MG
Volume of Ice Chips Taken From Lake(s):	2.20	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	M9923	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.19	none
Annual Potential Recharge (PR):	45.69	MG
Total Water Use:	4.79	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	40.90	MG
PR - Temporary Permitted Water:	41.00	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool
Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M9925		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.24747	151.48285	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	3.80	km2
Lake Surface Area(s):	1.02	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**M9925**	
Notes:		
		Units
Watershed to Lake Area Ratio:	3.73	none
Annual Potential Recharge (PR):	78.84	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	R0071		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	6.94	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.22433	151.65086	NAD83	

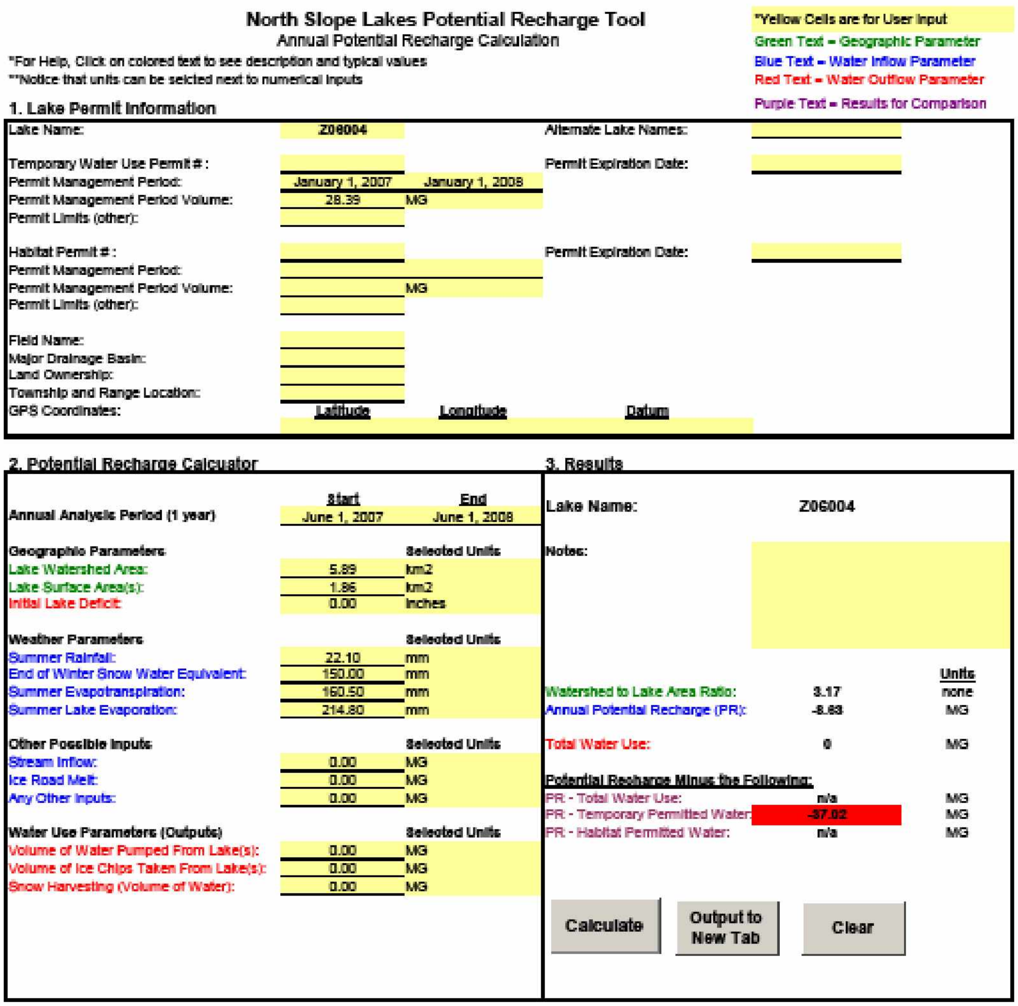
2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	1.76	km2
Lake Surface Area(s):	0.43	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		Selected Units
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

		Units
Lake Name:	R0071	
Notes:		
Watershed to Lake Area Ratio:	4.09	none
Annual Potential Recharge (PR):	35.94	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	29.00	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear



North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values

**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input

Green Text = Geographic Parameter

Blue Text = Water Inflow Parameter

Red Text = Water Outflow Parameter

Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	Z06004		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	28.39	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	5.89	km2
Lake Surface Area(s):	1.86	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	22.10	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	160.50	mm
Summer Lake Evaporation:	214.80	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	Z06004	
Notes:		
		Units
Watershed to Lake Area Ratio:	3.17	none
Annual Potential Recharge (PR):	-8.63	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	-37.02	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate

Output to New Tab

Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	Z06005		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	2.79	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	1.24	km2
Lake Surface Area(s):	0.38	km2
Initial Lake Deficit:		inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**Z06005**	
Notes:		
		Units
Watershed to Lake Area Ratio:	3.28	none
Annual Potential Recharge (PR):	24.88	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	21.89	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

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Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	Z06006		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	2.11	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	

2. Potential Recharge Calcuator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008

Geographic Parameters		**Selected Units**
Lake Watershed Area:	0.64	km2
Lake Surface Area(s):	0.11	km2
Initial Lake Deficit:		inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name: **Z06006**

Notes:

		Units
Watershed to Lake Area Ratio:	5.82	none
Annual Potential Recharge (PR):	13.46	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	11.35	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	Z06006		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	2.11	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		Selected Units
Lake Watershed Area:	0.64	km2
Lake Surface Area(s):	0.11	km2
Initial Lake Deficit:		inches
Weather Parameters		Selected Units
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		Selected Units
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		Selected Units
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

		Units
Lake Name:	Z06006	
Notes:		
Watershed to Lake Area Ratio:	5.82	none
Annual Potential Recharge (PR):	13.48	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	11.36	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	L9312		Alternate Lake Names:	U6.1
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2007		
Permit Management Period Volume:	30.16	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.33116	150.94957	NAD83	

2. Potential Recharge Calcuator

	Start	End
Annual Analysis Period (1 year)	January 1, 2006	January 1, 2007
Geographic Parameters		**Selected Units**
Lake Watershed Area:	1.03	km2
Lake Surface Area(s):	0.5	km2
Initial Lake Deficit:	0	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	22.6	mm
End of Winter Snow Water Equivalent:	117.2	mm
Summer Evapotranspiration:	89.6	mm
Summer Lake Evaporation:	119.8	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0	MG
Ice Road Melt:	0	MG
Any Other Inputs:	0	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	15.05	MG
Volume of Ice Chips Taken From Lake(s):	0	MG
Snow Harvesting (Volume of Water):	0	MG

3. Results

Lake Name:	L9312	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.06	none
Annual Potential Recharge (PR):	9.87	MG
Total Water Use:	15.06	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	-6.38	MG
PR - Temporary Permitted Water:	-20.49	MG
PR - Habitat Permitted Water:	n/a	MG

*To Return to Annual Analysis click on Annual Tab Below

North Slope Lakes Potential Recharge Tool

Seasonal Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	L9312		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	30.16	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Area:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.33116	150.94957	NAD83	

2. Potential Recharge Calcuator

Geographic Constants		Selected Units
Lake Watershed Area:	1.03	km2
Lake Surface Area(s):	0.5	km2
Winter Analysis		
Initial Lake Deficit:	0	mm
Snow Water Equivalent:	118.8	mm
Ice Road Within Watershed:		MG
Volume of Water Pumped From Lake(s):	10.25	MG
Volume of Ice Chips Taken From Lake(s):		MG
Snow Harvesting (Volume of Water):		MG
Summer Analysis		
Initial Lake Deficit:		mm
Rainfall:		mm
Evapotranspiration:		mm
Lake Evaporation:		mm
Stream Inflow:		MG
Volume of Water Pumped From Lake(s):		MG

3. Results

Lake Name:	L9312	
Notes:		
		Units
Watershed to Lake Area Ratio:	2.06	none
Winter Potential Recharge:	32.33	MG
Winter Water Use:	10.25	MG
Winter PR - Winter Water Use:	22.08	MG
Summer Potential Recharge:	n/a	MG
Summer Water Use:	n/a	MG
Summer PR - Summer Water Use:	n/a	MG
Total Potential Recharge (TPR):	32.33	MG
Total Water Use:	10.25	MG
Potential Recharge Minus the Following:		
TPR - Total Water Use:	22.08	MG
TPR - Temporary Permitted Water:	2.17	MG
TPR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	L9817		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2006	January 1, 2007		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.23310	151.34001	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	January 1, 2006	January 1, 2007
Geographic Parameters		**Selected Units**
Lake Watershed Area:	1.33	km2
Lake Surface Area(s):	0.5	km2
Initial Lake Deficit:	0	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.9	mm
End of Winter Snow Water Equivalent:	85.1	mm
Summer Evapotranspiration:	92.9	mm
Summer Lake Evaporation:	124.4	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0	MG
Ice Road Melt:	0	MG
Any Other Inputs:	0	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0	MG
Volume of Ice Chips Taken From Lake(s):	0	MG
Snow Harvesting (Volume of Water):	0	MG

3. Results

Lake Name: L9817

Notes:

		Units
Watershed to Lake Area Ratio:	2.66	none
Annual Potential Recharge (PR):	2.90	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Seasonal Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	L9817		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	15.3	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Area:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	**Latitude**	**Longitude**	**Datum**	
	70.23310	151.34001	NAD83	

2. Potential Recharge Calcuator

Geographic Constants		Selected Units
Lake Watershed Area:	1.33	km2
Lake Surface Area(s):	0.5	km2
Winter Analysis		
Initial Lake Deficit:	0	mm
Snow Water Equivalent:	105.3	mm
Ice Road Within Watershed:	0	MG
Volume of Water Pumped From Lake(s):	10.56	MG
Volume of Ice Chips Taken From Lake(s):	0	MG
Snow Harvesting (Volume of Water):	0	MG
Summer Analysis		
Initial Lake Deficit:		mm
Rainfall:		mm
Evapotranspiration:		mm
Lake Evaporation:		mm
Stream Inflow:		MG
Volume of Water Pumped From Lake(s):		MG

3. Results

Lake Name: L9817

Notes:

		Units
Watershed to Lake Area Ratio:	2.66	none
Winter Potential Recharge:	37.00	MG
Winter Water Use:	10.56	MG
Winter PR - Winter Water Use:	26.44	MG
Summer Potential Recharge:	n/a	MG
Summer Water Use:	n/a	MG
Summer PR - Summer Water Use:	n/a	MG
Total Potential Recharge (TPR):	37.00	MG
Total Water Use:	10.56	MG
Potential Recharge Minus the Following:		
TPR - Total Water Use:	26.44	MG
TPR - Temporary Permitted Water:	21.70	MG
TPR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0024		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	11.35	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	2.43	km2
Lake Surface Area(s):	0.71	km2
Initial Lake Deficit:		inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	7.74	MG
Volume of Ice Chips Taken From Lake(s):	2.68	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

Lake Name:	**M0024**	
Notes:		
		Units
Watershed to Lake Area Ratio:	3.42	none
Annual Potential Recharge (PR):	48.66	MG
Total Water Use:	10.42	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	38.24	MG
PR - Temporary Permitted Water:	37.31	MG
PR - Habitat Permitted Water:	n/a	MG

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North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
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*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0254		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.25281	151.57835	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008

Geographic Parameters		Selected Units
Lake Watershed Area:	1.04	km2
Lake Surface Area(s):	0.15	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

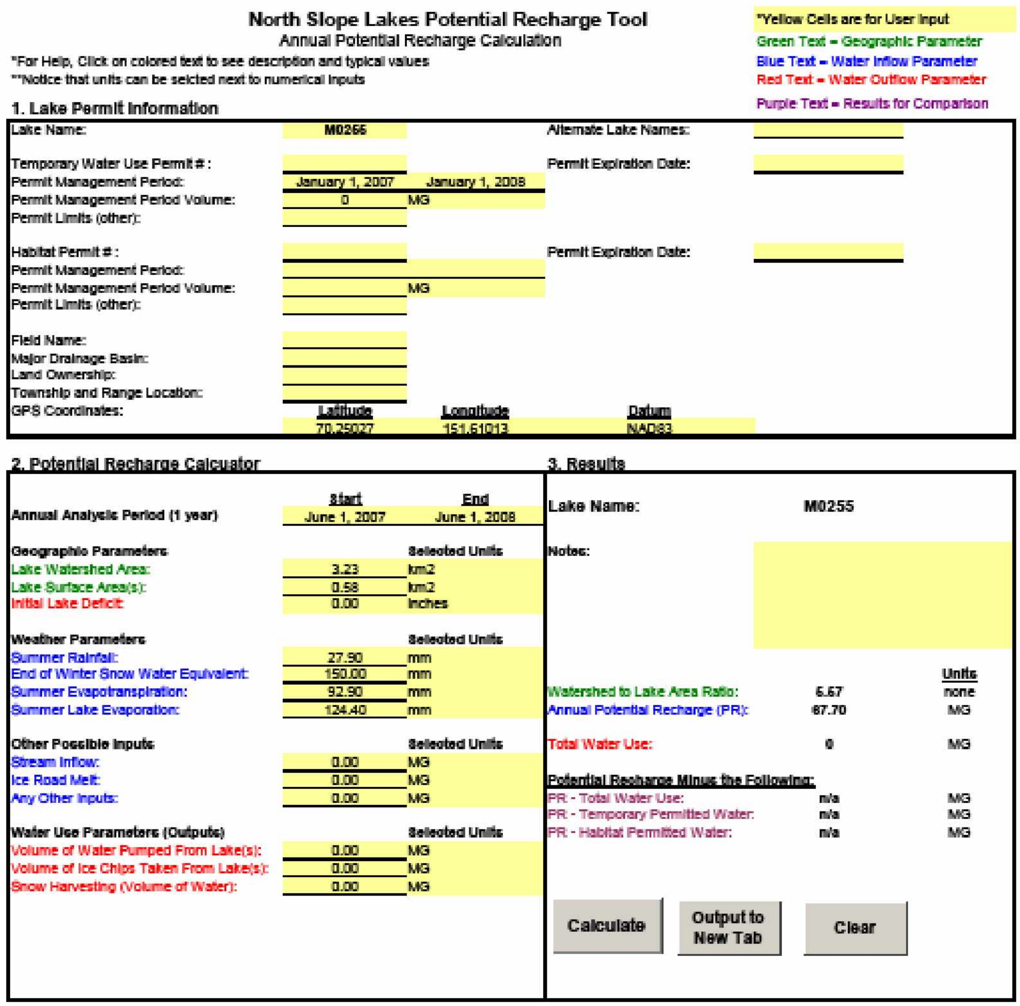
3. Results

Lake Name: M0254

Notes:

		Units
Watershed to Lake Area Ratio:	6.93	none
Annual Potential Recharge (PR):	22.10	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear



North Slope Lakes Potential Recharge Tool

Annual Potential Recharge Calculation

*For Help, Click on colored text to see description and typical values
**Notice that units can be selcted next to numerical inputs

*Yellow Cells are for User Input
Green Text = Geographic Parameter
Blue Text = Water Inflow Parameter
Red Text = Water Outflow Parameter
Purple Text = Results for Comparison

1. Lake Permit Information

Lake Name:	M0255		Alternate Lake Names:	
Temporary Water Use Permit # :			Permit Expiration Date:	
Permit Management Period:	January 1, 2007	January 1, 2008		
Permit Management Period Volume:	0	MG		
Permit Limits (other):				
Habitat Permit # :			Permit Expiration Date:	
Permit Management Period:				
Permit Management Period Volume:		MG		
Permit Limits (other):				
Field Name:				
Major Drainage Basin:				
Land Ownership:				
Township and Range Location:				
GPS Coordinates:	Latitude	Longitude	Datum	
	70.25027	151.61013	NAD83	

2. Potential Recharge Calculator

	Start	End
Annual Analysis Period (1 year)	June 1, 2007	June 1, 2008
Geographic Parameters		**Selected Units**
Lake Watershed Area:	3.23	km2
Lake Surface Area(s):	0.58	km2
Initial Lake Deficit:	0.00	inches
Weather Parameters		**Selected Units**
Summer Rainfall:	27.90	mm
End of Winter Snow Water Equivalent:	150.00	mm
Summer Evapotranspiration:	92.90	mm
Summer Lake Evaporation:	124.40	mm
Other Possible Inputs		**Selected Units**
Stream Inflow:	0.00	MG
Ice Road Melt:	0.00	MG
Any Other Inputs:	0.00	MG
Water Use Parameters (Outputs)		**Selected Units**
Volume of Water Pumped From Lake(s):	0.00	MG
Volume of Ice Chips Taken From Lake(s):	0.00	MG
Snow Harvesting (Volume of Water):	0.00	MG

3. Results

		Units
Lake Name:	M0255	
Notes:		
Watershed to Lake Area Ratio:	5.57	none
Annual Potential Recharge (PR):	67.70	MG
Total Water Use:	0	MG
Potential Recharge Minus the Following:		
PR - Total Water Use:	n/a	MG
PR - Temporary Permitted Water:	n/a	MG
PR - Habitat Permitted Water:	n/a	MG

Calculate | Output to New Tab | Clear

Appendix B – Moulton's Lake Bathymetry for Selected Study Lakes

Lake M9922

Other Names: None Known
Location: 70.22845°N 151.58689°W
USGS Quad Sheet: Harrison Bay A-3: T10N R2E Sec. 10-11, 14-15
Habitat: Tundra lake
Area: 196 acres
Maximum Depth: 6.1 feet
Active Outlet: No
Total Lake Volume: 246.9 million gallons (2002 data)
Volume Under 4 ft of ice: 31.2 million gallons
Volume Under 5 ft of ice: 4.4 million gallons
Volume Under 7 ft of ice: 0.0 million gallons

Potential Aggregate: 63.1 acres (water depth 4 ft or less)
4.94 million gallons

Maximum Recommended Winter Removal: **1.32 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
1999	16.5	4.1	6.2	23.8	58	136	--	7.77	L. Moulton
2000	14.5	3.3	5.2	19.9	50	135	--	7.79	L. Moulton
2002	--	--	--	--	--	152	2.0	7.92	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 15 99	6.4	None	0
Gill Net	Aug 1 00	6.9	None	0
Minnow Traps	Aug 1 00	21.3	Ninespine stickleback	seen
Fyke Net	Jul 28 to Aug 2 02	135.9	Ninespine stickleback	199

Lake M9923

Other Names: None Known
Location: 70.22754°N 151.52430°W
USGS Quad Sheet: Harrison Bay A-3: T10N R2E Sec. 12-13
Habitat: Tundra lake
Area: 255 acres
Maximum Depth: 6.7 feet
Active Outlet: No
Total Lake Volume: 289.6 million gallons (2002 data)
Volume Under 4 ft of ice: 52.8 million gallons
Volume Under 5 ft of ice: 15.6 million gallons
Volume Under 7 ft of ice: 0.0 million gallons

Potential Aggregate: 118.8 acres (water depth 4 ft or less)
9.29 million gallons

Maximum Recommended Winter Removal: **4.69 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
1999	38.4	6.3	6.8	24.1	122	253	--	8.23	L. Moulton
2000	33.0	4.9	5.4	18.8	103	225	--	8.20	L. Moulton
2002	--	--	--	--	--	256	1.9	8.18	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 17 99	4.0	None	0
Gill Net	Aug 1 00	10.1	None	0
Minnow Traps	Aug 1 00	15.4	None	0
Fyke Net	Jul 29 to Aug 2 02	116.0	Ninespine stickleback	632

Lake M9925

Other Names: None Known
Location: 70.24747°N 151.48285°W
USGS Quad Sheet: Harrison Bay B-3: T10N R3E Sec. 6
Habitat: Tundra lake
Area: 212 acres
Maximum Depth: 3.9 feet
Active Outlet: No
Total Lake Volume: 89.7 million gallons (1999 data)
Volume Under 4 ft of ice: 0.0 million gallons
Volume Under 5 ft of ice: 0.0 million gallons
Volume Under 7 ft of ice: 0.0 million gallons

Potential Aggregate: 211.7 acres (water depth 4 ft or less)
16.57 million gallons

Maximum Recommended Winter Removal: **0.00 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
1999	40.2	6.2	11.1	37.8	122	276	--	8.12	L. Moulton
Aug 03 02	--	--	--	--	--	312	6.2	8.28	L. Moulton
Aug 04 02	--	--	--	--	--	316	11.8	8.14	L. Moulton
Aug 06 02	--	--	--	--	--	308	7.8	7.86	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill net	Jul 18 99	6.4	None	0
Fyke Net	Aug 3-6, 02	92.1	Ninespine stickleback	2,243

Lake M0403

Other Names:			
Location:	70.38960°N 153.52083°W		
USGS Quad Sheet:	Teshekpuk B-1: T12N R6/7W Sec. 18/19/13/24		
Habitat:	Tundra Lake		
Area:	401 acres		
Maximum Depth:	6.9 feet		
Active Outlet:	No		
Total Lake Volume:		437.21 million gallons	(July 14, 2004 data)
Water Volume Under 4 ft of ice:		82.08 million gallons	
Water Volume Under 5 ft of ice:		20.43 million gallons	
Water Volume Under 7 ft of ice:		0.00 million gallons	
Potential Ice Aggregate:		180.2 acres (water depth 4 ft or less)	
		14.10 million gallons	

Maximum Recommended Winter Removal: **6.13 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2004	11.2	1.1	1.3	2.6	32	75	1.0	7.80	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 14 04	7.0	None	0
Observed	Jul 14 04	--	Ninespine stickleback	2

Lake M0404

Other Names:			
Location:	70.31562°N 153.50552°W		
USGS Quad Sheet:	Teshekpuk B-1: T11N R6W Sec. 7/18		
Habitat:	Drainage Lake		
Area:	235 acres		
Maximum Depth:	22.1 feet		
Active Outlet:	Yes		
Total Lake Volume:		426.67 million gallons	(July 24, 2004 data)
Water Volume Under 4 ft of ice:		194.57 million gallons	
Water Volume Under 5 ft of ice:		159.16 million gallons	
Water Volume Under 7 ft of ice:		105.87 million gallons	

Potential Ice Aggregate: 115.8 acres (water depth 4 ft or less)
9.06 million gallons

Maximum Recommended Winter Removal: **15.88 million gallons**
(15% of water volume under 7 ft of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2004	10.4	1.7	3.5	7.7	33	87	0.8	7.92	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught	Fork Length (mm)
Gill Net	Jul 24 04	7.5	Least cisco	4	129-238
Minnow Trap	Jul 24 04	7.0	Ninespine stickleback	3	
Observed	Jul 24 04	–	Ninespine stickleback	+	

Lake M0405

Other Names:			
Location:	70.32823°N 153.49310°W		
USGS Quad Sheet:	Teshekpuk B-1: T11N R6W Sec. 6/7		
Habitat:	Tundra Lake		
Area:	111 acres		
Maximum Depth:	6.8 feet		
Active Outlet:	No		
Total Lake Volume:		97.95 million gallons	(July 27, 2004 data)
Water Volume Under 4 ft of ice:		11.49 million gallons	
Water Volume Under 5 ft of ice:		2.65 million gallons	
Water Volume Under 7 ft of ice:		0.00 million gallons	
Potential Ice Aggregate:		70.5 acres (water depth 4 ft or less) 5.51 million gallons	

Maximum Recommended Winter Removal: **19.59 million gallons**
(No fish concern, 20% of lake volume)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2004	13.0	3.2	3.3	6.0	45	94	1.9	7.98	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 27 04	8.6	None	0
Minnow Trap	Jul 27 04	11.3	None	0
Seine	Jul 27 04	3 hauls	None	0

Lake M0406

Other Names:

	Basin A	Basin B	
Location:	70.32802°N 153.47480°W	70.32975°N 153.46716°W	
USGS Quad Sheet:	Teshekpuk B-1: T11N R6W Sec. 5/8	Teshekpuk B-1: T11N R6W Sec. 5/8	
Habitat:	Tundra Lake	Tundra Lake	
Area:	111.0	74.1	acres
Maximum Depth:	7.0	--	(shallow)
Active Outlet:	No	No	
Total Lake Volume:	58.38	?	million gallons
Water Volume Under 4 ft of ice:	2.19	0.00	million gallons
Water Volume Under 5 ft of ice:	0.94	0.00	million gallons
Water Volume Under 7 ft of ice:	0.00	0.00	million gallons
Potential Ice Aggregate:	106.1	74.1	acres (water depth 4 ft or less)
	8.30	5.80	million gallons

(July 28, 2004 data)

	Basin A	Basin B	
Maximum Recommended Winter Removal:	**11.68**	**0.00**	**million gallons**

(No fish concern, 20% of lake volume)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2004	16.7	2.9	4.3	7.6	54	118	1.1	7.97	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 28 04	8.2	None	0
Minnow Trap	Jul 28 04	10.8	None	0

Lake M0407

	Basin A	Basin B
Other Names:		
Location:	70.35703°N 153.41198°W	70.35848°N 153.44023°W
USGS Quad Sheet:	Teshekpuk B-1: T12N R6W Sec. 27/28/33/34	Teshekpuk B-1: T12N R6W Sec. 28/33
Habitat:	Tundra Lake	Tundra Lake
Area:	491.0	73.2 acres
Maximum Depth:	6.8	6.9 (shallow)
Active Outlet:	No	No
Total Lake Volume:	497.03	101.18 million gallons
Water Volume Under 4 ft of ice:	74.03	20.43 million gallons
Water Volume Under 5 ft of ice:	27.53	7.86 million gallons
Water Volume Under 7 ft of ice:	3.32	0.00 million gallons
Potential Ice Aggregate:	334.5	27.1 acres (water depth 4 ft or less)
	26.2	2.12 million gallons

	Basin C	Basin D
Other Names:		
Location:	70.36169°N 153.43353°W	70.36234°N 153.39198°W
USGS Quad Sheet:	Teshekpuk B-1: T12N R6W Sec. 28	Teshekpuk B-1: T12N R6W Sec. 27
Habitat:	Tundra Lake	Tundra Lake
Area:	19	30 acres
Maximum Depth:	6.4	7.5 (shallow)
Active Outlet:	No	No
Total Lake Volume:	16.22	30.15 million gallons
Water Volume Under 4 ft of ice:	0.96	3.44 million gallons
Water Volume Under 5 ft of ice:	0.24	0.97 million gallons
Water Volume Under 7 ft of ice:	0.00	0.00 million gallons
Potential Ice Aggregate:	15.5	19.1 acres (water depth 4 ft or less)
	1.21	1.50 million gallons

(July 29, 2004 data)

	Basin A	Basin B	Basin C	Basin D	
Max. Recommended Winter Removal:	**99.41**	**20.24**	**3.24**	**6.03**	**million gallons**

(No fish concern, 20% of lake volume)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2004	12.5	1.4	2.1	3.4	37	73	0.6	8.19	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 29 04	8.3	None	0
Minnow Trap	Jul 29 04	11.8	None	0
Seine	Jul 29 04	3 hauls	None	0

Lake M0408

Other Names:
Location: 70.37295°N 153.36591°W
USGS Quad Sheet: Teshekpuk B-1: T12N R6W Sec. 22/23/26/27
Habitat: Tundra Lake
Area: 270 acres
Maximum Depth: 9.2 feet
Active Outlet: No
Total Lake Volume: 258.92 million gallons (July 23, 2004 data)
Water Volume Under 4 ft of ice: 95.35 million gallons
Water Volume Under 5 ft of ice: 66.91 million gallons
Water Volume Under 7 ft of ice: 14.81 million gallons

Potential Aggregate: 180.9 acres (water depth 4 ft or less)
14.16 million gallons

Maximum Recommended Winter Removal: **51.78 million gallons**
(No fish concern, 20% of lake volume)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2004	31.9	3.3	4.1	7.1	93	177	0.4	8.07	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 23 04	9.5	None	0
Minnow Trap	Jul 23 04	12.0	None	0
Seine	Jul 23 04	3 hauls	None	0

Lake M0409

Other Names:
Location: 70.36423°N 153.31113°W
USGS Quad Sheet: Teshekpuk B-1: T12N R6W Sec. 25/26
Habitat: Drainage Lake
Area: 552 acres
Maximum Depth: 27.8 feet
Active Outlet: Yes
Total Lake Volume: 747.34 million gallons (July 23, 2004 data)
Water Volume Under 4 ft of ice: 224.89 million gallons
Water Volume Under 5 ft of ice: 159.48 million gallons
Water Volume Under 7 ft of ice: 89.08 million gallons

Potential Aggregate: 302.3 acres (water depth 4 ft or less)
23.66 million gallons

Maximum Recommended Winter Removal: **47.84 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2004	28.9	3.4	5.3	10.1	86	171	0.7	7.91	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 23 04	9.3	None	0
Minnow Trap	Jul 23 04	10.8	Ninespine stickleback	3
Observed	Jul 23 04	--	Ninespine stickleback	100's

Lake M0302

Other Names:
Location: 70.25719°N 152.17616°W
USGS Quad Sheet: Harrison Bay B-4: T11N R1W Sec. 4/5/32/33
Habitat: Tundra Lake
Area: 56 acres
Maximum Depth: 9.4 feet
Active Outlet: No
Total Lake Volume: 93.93 million gallons (July 12, 2003 data)
Water Volume Under 4 ft of ice: 47.21 million gallons
Water Volume Under 5 ft of ice: 42.66 million gallons
Water Volume Under 7 ft of ice: 21.82 million gallons

Potential Aggregate: 16.9 acres (water depth 4 ft or less)
1.32 million gallons

Maximum Recommended Winter Removal: **3.27 million gallons**
(15% of water volume under 7 ft of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2003	22.0	5.5	22	39	77	276	1.0	8.22	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught	Fork Length (mm)
Gill Net	Jul 12 03	3.0	Least cisco	1	150
Minnow Trap	Jul 12 03	7.5	None	0	

Lake M0303

Other Names:
Location: 70.26706°N 152.20824°W
USGS Quad Sheet: Harrison Bay B-4: T11N R1W Sec. 32
Habitat: Drainage Lake
Area: 61 acres
Maximum Depth: 9.8 feet
Active Outlet: No
Total Lake Volume: 123.89 million gallons (July 13, 2003 data)
Water Volume Under 4 ft of ice: 49.31 million gallons
Water Volume Under 5 ft of ice: 33.88 million gallons
Water Volume Under 7 ft of ice: 9.76 million gallons

Potential Aggregate: 16.0 acres (water depth 4 ft or less)
1.25 million gallons

Maximum Recommended Winter Removal: **10.17 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2003	11.0	1.9	4.8	11	36	104	1.9	7.92	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 13 03	4.8	None	0
Minnow Trap	Jul 13 03	4.7	None	0
Seine	Jul 13 03	2 hauls	Ninespine stickleback	2

Lake M0304

Other Names:

	Basin A	Basin B	
Location:	70.26801°N 152.22509°W	70.26993°N 152.24909°W	
USGS Quad Sheet:	Harrison Bay B-4: T11N R1W Sec. 30/31		
Habitat:	Tundra Lake	Tundra Lake	
Area:	74	37	acres
Maximum Depth:	9.2	8.2	feet
Active Outlet:	No	No	
Total Lake Volume:	119.27	43.34	million gallons
Water Volume Under 4 ft of ice:	34.86	5.92	million gallons
Water Volume Under 5 ft of ice:	18.99	1.68	million gallons
Water Volume Under 7 ft of ice:	1.12	0.05	million gallons
Potential Aggregate:	25.1	17.6	acres (water depth 4 ft or less)
	1.96	1.38	million gallons

(July 15, 2003 data)

	Basin A	Basin B	
Maximum Recommended Winter Removal:	**23.85**	**8.67**	**million gallons**

No fish concern, 20% of lake volume)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2003	10.0	1.8	10.0	3.7	32	96	1.2	7.69	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 15 03	5.4	None	0
Minnow Trap	Jul 15 03	6.0	None	0
Seine	Jul 15 03	3 hauls	None	0

Lake M0305

Other Names:
Location: 70.28695°N 152.19686°W
USGS Quad Sheet: Harrison Bay B-4: T11N R1W Sec. 16/17/20/21/29
Habitat: Tundra Lake
Area: 743 acres
Maximum Depth: 8.7 feet
Active Outlet: No
Total Lake Volume: 665.85 million gallons (July 24, 2003 data)
Water Volume Under 4 ft of ice: 189.48 million gallons
Water Volume Under 5 ft of ice: 96.26 million gallons
Water Volume Under 7 ft of ice: 4.33 million gallons

Potential Aggregate: 142.0 acres (water depth 4 ft or less)
11.11 million gallons

Maximum Recommended Winter Removal: **28.88 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2003	18.0	2.8	6.4	15	56	141	3.4	7.95	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 24 03	6.0	None	0
Minnow Trap	Jul 24 03	6.0	Ninespine stickleback	3

Lake M0306

	Basin A	Basin B	
Other Names:			
Location:	70.27827°N 152.25843°W	70.27712°N 152.27401°W	
USGS Quad Sheet:	Harrison Bay B-4: T11N R2W Sec. 25/30		
Habitat:	Tundra Lake	Tundra Lake	
Area:	79	44	acres
Maximum Depth:	7.5	7.5	feet
Active Outlet:	No	No	
Total Lake Volume:	107.99	67.84	million gallons
Water Volume Under 4 ft of ice:	25.50	15.13	million gallons
Water Volume Under 5 ft of ice:	10.49	5.23	million gallons
Water Volume Under 7 ft of ice:	0.03	0.06	million gallons
Potential Aggregate:	22.4	10.9	acres (water depth 4 ft or less)
	1.75	0.85	million gallons

(July 15, 2003 data)

	Basin A	Basin B	
Maximum Recommended Winter Removal:	**21.60**	**13.57**	**million gallons**

(No fish concern, 20% of lake volume)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2003	11.0	1.8	11.0	5.8	36	107	0.5	7.69	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 15 03	6.0	None	0
Minnow Trap	Jul 15 03	9.0	None	0
Seine	Jul 15 03	3 hauls	None	0

Lake M0307

Other Names:
Location: 70.26838°N 152.28894°W
USGS Quad Sheet: Harrison Bay B-4: T11N R2W Sec. 25/36
Habitat: Tundra Lake
Area: 227 acres
Maximum Depth: 7.0 feet
Active Outlet: No
Total Lake Volume: 298.24 million gallons (July 14, 2003 data)
Water Volume Under 4 ft of ice: 48.97 million gallons
Water Volume Under 5 ft of ice: 11.05 million gallons
Water Volume Under 7 ft of ice: 0.00 million gallons

Potential Aggregate: 65.9 acres (water depth 4 ft or less)
5.16 million gallons

Maximum Recommended Winter Removal: **3.31 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2003	14.0	2.2	5.9	13.0	43	120	0.7	7.91	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 13 03	5.5	None	0
Minnow Trap	Jul 13 03	6.2	None	0
Seine	Jul 13 03	3 hauls	Ninespine stickleback	1

Lake L9312

Other Names: U6.1
Location: 70.33116°N 150.94957°W
USGS Quad Sheet Harrison Bay B-2: T11N R5E, Sec. 5
Habitat: Perched Lake (Infrequent Flooding)
Area: 111 acres
Maximum Depth: 14.1 feet
Active Outlet: No
Total Lake Volume: 323.46 million gallons (2002 data)
Water Volume Under 4 ft of ice: 190.60 million gallons
Water Volume Under 5 ft of ice: 159.70 million gallons
Water Volume Under 7 ft of ice: 100.55 million gallons

Potential Ice Aggregate: 15.40 acres (water depth 4 ft or less)
1.20 million gallons

Maximum Recommended Winter Removal: **30.16 million gallons**
(30% of water volume under 7 ft of ice)
(special permit request)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Total Dissolved Solids (mg/l)	pH	Source
1993	7.2	2.1	4.5	8.0	27	--	150	--	J. Lobdell
1995	--	--	--	--	--	60	--	7.70	L. Moulton
1997	--	--	--	--	--	82.7	--	7.85	L. Moulton

Water chemistry was monitored annually from 1999 to 2006, contact CPAI for access to reports.

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught	Fork Length (mm)
Fyke Net	Jul 14 95	23.9	Alaska blackfish	1	
			Slimy sculpin	1	
			Ninespine stickleback	10	
Fyke Net	Jul 26 95	20.0	Broad whitefish	1	428
			Ninespine stickleback	2	
Minnow Trap	Jul 14 95	48.6	Slimy sculpin	2	
			Ninespine stickleback	1	
Set Line	Jul 14 95	23.5	None	0	
Gill Net	Nov 2 95	21.7	Least cisco	62	116-303
			Broad whitefish	5	334-470
Fyke Net	Jul 11-15 97	116.6	Least cisco	1	56
			Alaska blackfish	5	70
			Slimy sculpin	8	38-84
			Ninespine stickleback	57	

This lake was monitored annually from 1999 to 2006, contact CPAI for access to reports with detailed catch records.

Lake L9817

Other Names:
Location: 70.23310°N 151.34001°W
USGS Quad Sheet: Harrison Bay A-3: T10N R3E Sec. 10
Habitat: Tundra Lake
Area: 62 acres
Maximum Depth: 9.3 feet

Estimated Water Volume:

Total Volume (mil. gals)	Volume Under 4 ft of Ice (mil. gals)	Volume Under 5 ft of Ice (mil. gals)	Volume Under 7 ft of Ice (mil. gals)	
104.88	32.55	18.32	3.02	(based on 2004 bathymetry)

Water Chemistry:

Date	Specific Conductance (microS/cm)	Turbidity (NTU)	pH
Jul 30 02	222	1.3	8.21
Jul 31 02	237	1.2	8.10
Aug 01 02	238	1.3	8.25
Aug 02 02	239	1.2	8.15
Aug 03 02	241	1.3	8.26
Aug 04 02	244	1.5	8.04
Jul 15 04	221	1.0	7.05
Jul 16 04	224	0.8	7.60
Jul 17 04	224	0.7	7.72
Jul 18 04	226	0.8	7.70
Jul 19 04	228	0.8	7.74
Jul 28 04	236	0.6	7.79

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 17 99	7.5	None	0
Fyke Net	Jul 30 02	25.1	Ninespine stickleback	100
	Jul 31 02	19.5	Ninespine stickleback	154
	Aug 01 02	22.5	Ninespine stickleback	6,000
	Aug 02 02	25.2	Ninespine stickleback	3,000
	Aug 03 02	22.7	Ninespine stickleback	15,000
	Aug 04 02	25.6	Ninespine stickleback	7,500
	Jul 16 04	26.7	None	0
	Jul 17 04	24.4	Ninespine stickleback	1
	Jul 18 04	20.3	None	0
	Jul 19 04	24.5	None	0

Lake R0071

Other Names:
Location: 70.22433°N 151.65086°W
USGS Quad Sheet: Harrison Bay A-5/B-5: T10N R2E, Sec. 16
Habitat: Drainage Lake
Area: 80.9 acres
Maximum Depth: 2.7 feet
Active Outlet: Yes
Total Lake Volume: 34.7 million gallons (July 17, 2005 data)
Water Volume Under 4 ft of ice: 0.0 million gallons
Water Volume Under 5 ft of ice: 0.0 million gallons
Water Volume Under 7 ft of ice: 0.0 million gallons

Potential Ice Aggregate: 80.9 acres (water depth 4 ft or less)
6.33 million gallons

Maximum Recommended Winter Removal: **0.000 million gallons**
(lake is less than 4 feet deep)

Water Use History:

Year	Water Removed (all sources) (mill. Gals)
	none

Water Chemistry:

Year of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2005	11.0	2.7	5.2	12.0	39	95	13	7.81	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 17 05	6.8	None	0
Minnow traps	Jul 17 05	7.0	None	0

Lake M9914

Other Names: None Known
Location: 70°14.00'N 150°37.84'W
USGS Quad Sheet: Harrison Bay A-3: T10N R2E Sec. 9
Habitat: Tundra lake
Area: 151 acres
Maximum Depth: 7.8 feet
Active Outlet: Yes
Total Lake Volume: 205.08 million gallons (2002 data)
Water Volume Under 4 ft of ice: 39.29 million gallons
Water Volume Under 5 ft of ice: 11.48 million gallons
Water Volume Under 7 ft of ice: 0.00 million gallons

Potential Ice Aggregate: 50.5 acres (water depth 4 ft or less)
3.95 million gallons

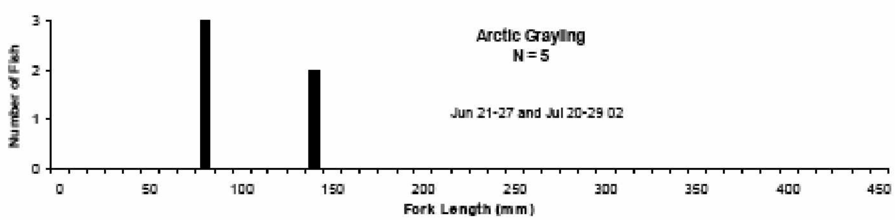
Maximum Recommended Winter Removal: **0.00 million gallons**
(15% of water volume under 7 ft of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l)	Magnesium (mg/l	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Total Dissolved Solids (mg/l)	pH	Source
1999	10.1	2.4	4.5	12.1	35.9	99	74	7.45	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 12 99	2.0	None	0
Fyke Net	Jun 21-27 02	161.9	Arctic grayling	2
			Alaska blackfish	2
			Ninespine stickleback	49
	Jul 20-29 02	235.1	Arctic grayling	3
			Alaska blackfish	4
			Ninespine stickleback	507



Lake M0256

Other Names:
Location: 70.24439°N 151.60801°W
USGS Quad Sheet: Harrison Bay B-3: T10N R2E Sec. 3
Habitat: Tundra Lake
Area: 30 acres
Maximum Depth: 9.0 feet
Active Outlet:
Total Lake Volume: 48.00 million gallons (September 5, 2002 data)
Water Volume Under 4 ft of ice: 16.12 million gallons
Water Volume Under 5 ft of ice: 9.70 million gallons
Water Volume Under 7 ft of ice: 1.13 million gallons

Potential Ice Aggregate: 9.2 acres (water depth 4 ft or less)
0.72 million gallons

Maximum Recommended Winter Removal: **2.91 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Date of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2002	--	--	--	--	--	86.7	1.4	7.73	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Fyke Net	Aug 5-6 2002	47.1	Alaska blackfish	1
			Ninespine stickleback	554

Lake M0255

Other Names:			
Location:	70.25027°N 151.61012°W		
USGS Quad Sheet:	Harrison Bay A/B-3: T10N R2E Sec. 3		
Habitat:	Tundra Lake		
Area:	67 acres		
Maximum Depth:	3.9 feet		
Active Outlet:	No		
Total Lake Volume:		56.80 million gallons	(July 12, 2004 data)
Water Volume Under 4 ft of ice:		0.00 million gallons	
Water Volume Under 5 ft of ice:		0.00 million gallons	
Water Volume Under 7 ft of ice:		0.00 million gallons	

Potential Ice Aggregate: 67.3 acres (water depth 4 ft or less)
5.27 million gallons

Maximum Recommended Winter Removal: **0.00 million gallons**
(too shallow)

Water Chemistry:

Date of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
Aug 3 04	--	--	--	--	--	24.5	1.8	8.11	L. Moulton
Aug 4 04	--	--	--	--	--	104.2	1.3	7.99	L. Moulton
Jul 12 04	--	--	--	--	--	67.3	1.5	7.40	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Fyke Net	Aug 2-3, 02	44.3	Ninespine stickleback	142

Lake M9912

Other Names: None Known
Location: 70.25178°N 151.55677°W
USGS Quad Sheet: Harrison Bay B-3: T10N R2E Sec. 2
Habitat: Tundra lake
Area: 35 acres
Maximum Depth: 9.6 feet
Active Outlet: No
Total Lake Volume: 61.93 million gallons (2002 data)
Water Volume Under 4 ft of ice: 20.13 million gallons
Water Volume Under 5 ft of ice: 11.22 million gallons
Water Volume Under 7 ft of ice: 0.82 million gallons

Potential Ice Aggregate: 5.6 acres (water depth 4 ft or less)
0.44 million gallons

Maximum Recommended Winter Removal: **3.36 million gallons**
(30% of water volume under 5 ft of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l)	Magnesium (mg/l	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Total Dissolved Solids (mg/l)	pH	Source
1999	8.63	2.2	4.4	13.9	31.4	88	59	7.38	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught	Fork Length (mm)
Gill Net	Jul 12 99	5.5	None	0	
Fyke Net	Jul 28 to Aug 2 02	0.0	Alaska blackfish	53	44-117
			Ninespine stickleback	76	

Lake M0254

Other Names:
Location: 70.25281°N 151.58735°W
USGS Quad Sheet: Harrison Bay B-3: T10N R2E Sec. 3
Habitat: Tundra Lake
Area: 30 acres
Maximum Depth: 12.7 feet
Active Outlet:
Total Lake Volume: 59.40 million gallons (September 5, 2002 data)
Water Volume Under 4 ft of ice: 26.45 million gallons
Water Volume Under 5 ft of ice: 15.60 million gallons
Water Volume Under 7 ft of ice: 7.33 million gallons

Potential Ice Aggregate: 8.9 acres (water depth 4 ft or less)
0.69 million gallons

Maximum Recommended Winter Removal: **4.68 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Date of Test	Calcium (mg/l	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
Aug 03 02	--	--	--	--	--	115.5	0.8	8.09	L. Moulton
Aug 04 02	--	--	--	--	--	116.9	1.4	7.91	L. Moulton
Aug 06 02	--	--	--	--	--	115.7	1.2	7.70	L. Moulton

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Fyke Net	Aug 3-6 2002	92.3	Alaska blackfish	58
			Ninespine stickleback	1400

Lake M9913

Other Names: None Known
Location: 70.25157°N 151.54264°W
USGS Quad Sheet: Harrison Bay B-3: T10N R2E Sec. 2
Habitat: Tundra lake
Area: 20 acres
Maximum Depth: 7.9 feet
Active Outlet: No
Total Lake Volume: 29.77 million gallons (1999 data)
Water Volume Under 4 ft of ice: 8.05 million gallons
Water Volume Under 5 ft of ice: 4.18 million gallons
Water Volume Under 7 ft of ice: 0.14 million gallons

Potential Ice Aggregate: 7.1 acres (water depth 4 ft or less)
0.55 million gallons

Maximum Recommended Winter Removal: **1.25 million gallons**
(Potential for resistant species, 30% of water volume under 5 ft of ice)
(does not include volume associated with ice aggregate)

Water Chemistry:

Year of Test	Calcium (mg/l)	Magnesium (mg/l	Sodium (mg/l)	Chloride (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Total Dissolved Solids (mg/l)	pH	Source
1999	9.21	2.1	3.9	11.9	32	86	55	7.37	L. Moulton

Catch Record:

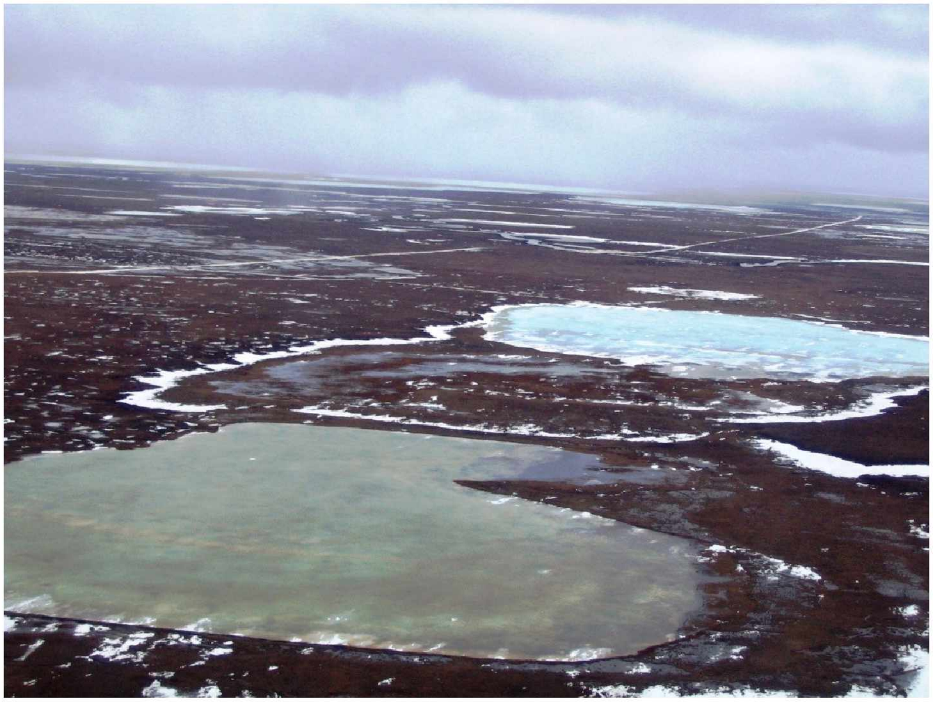
Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 12 99	5.4	None	0

Appendix C – Aerial Photographs Documenting Lake Recharge for 2008

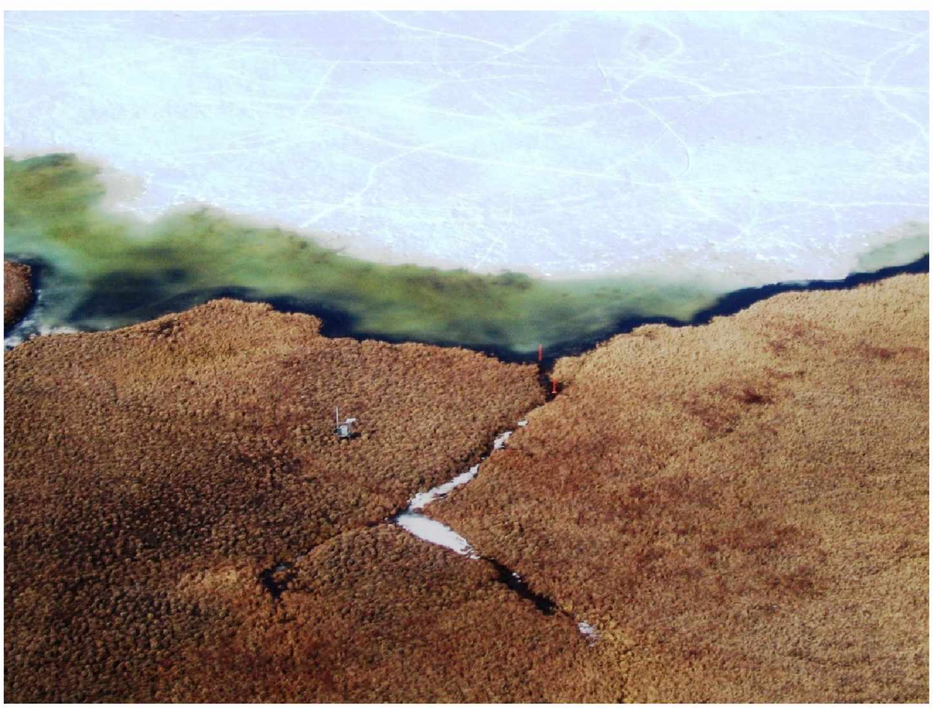
<u>**Lake L9312 June 1, 2008**</u>

<u>**Lake L9312 May 30, 2008**</u>

Lake L9817   June 3, 2008

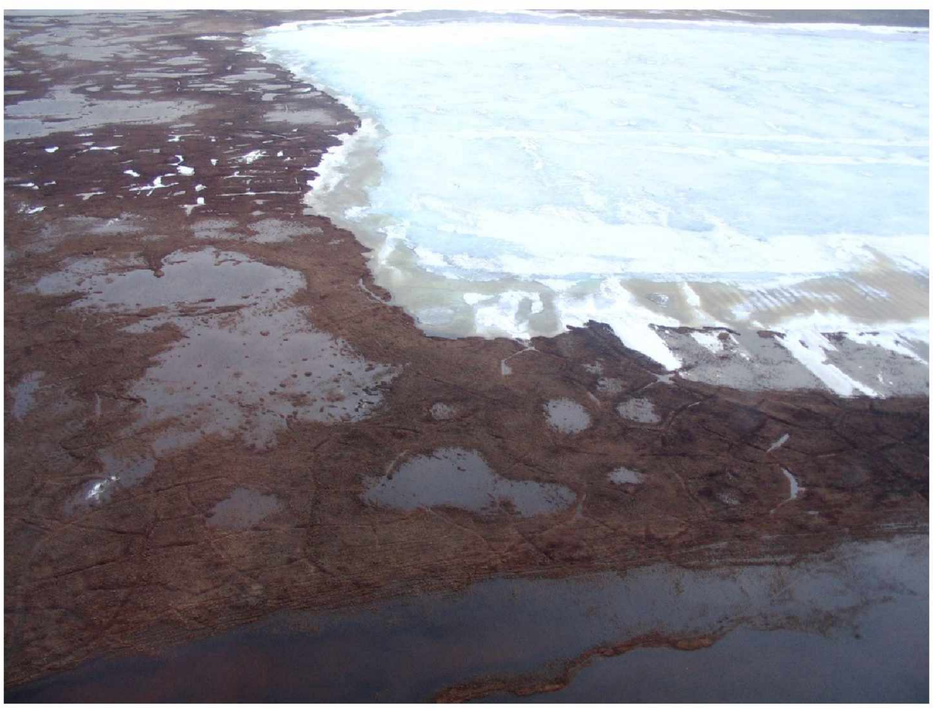


Lake 9817 Outlet   June 3, 2008

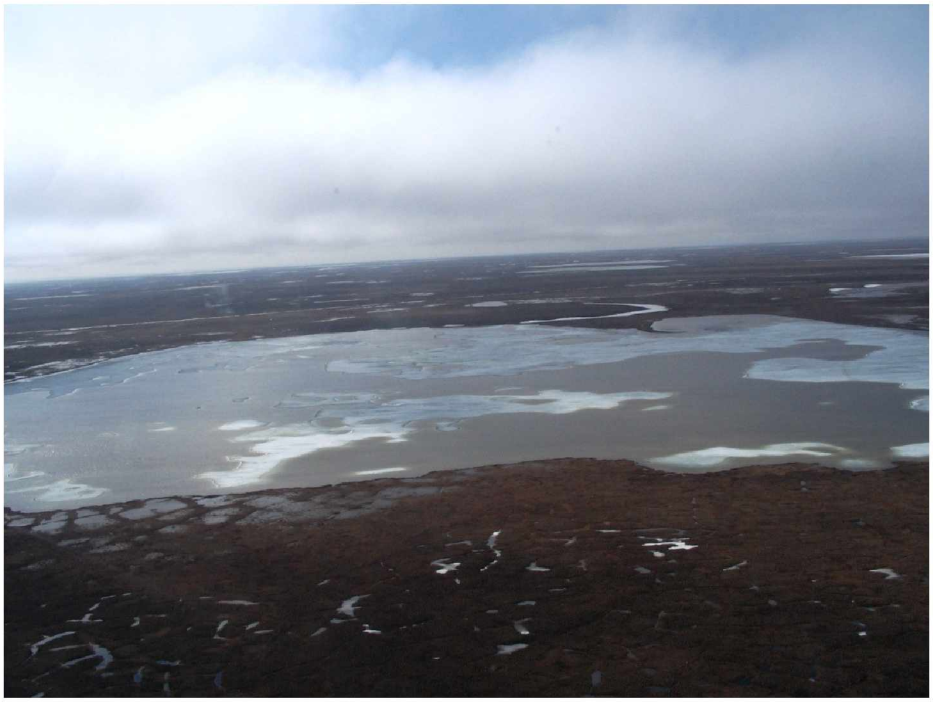


Lake M0024 June 3, 2008

Lake M0024 Outlet June 3, 2008

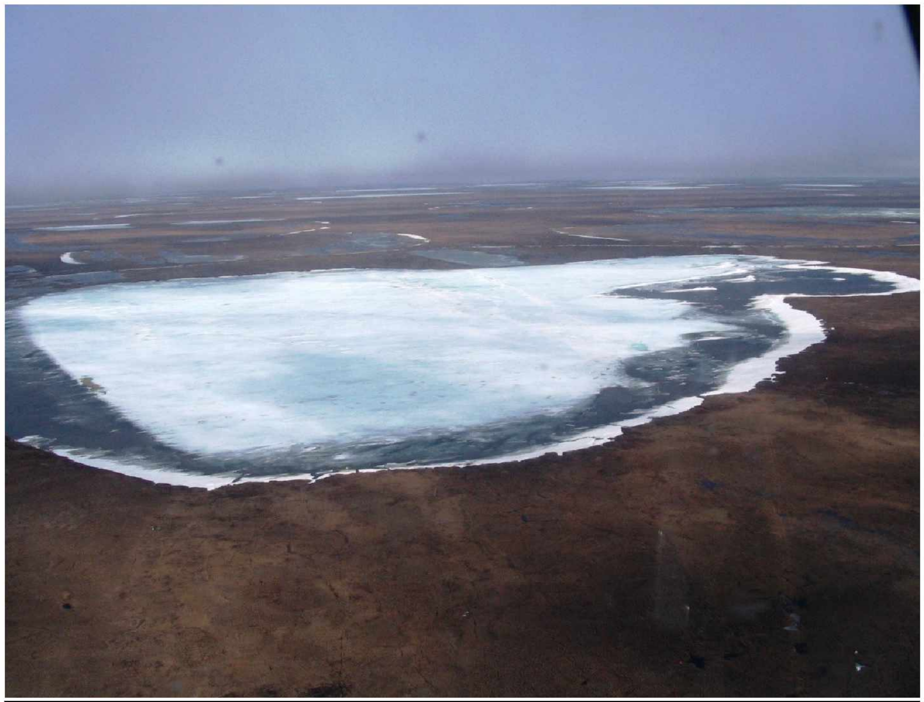


Lake M9922 June 3, 2008

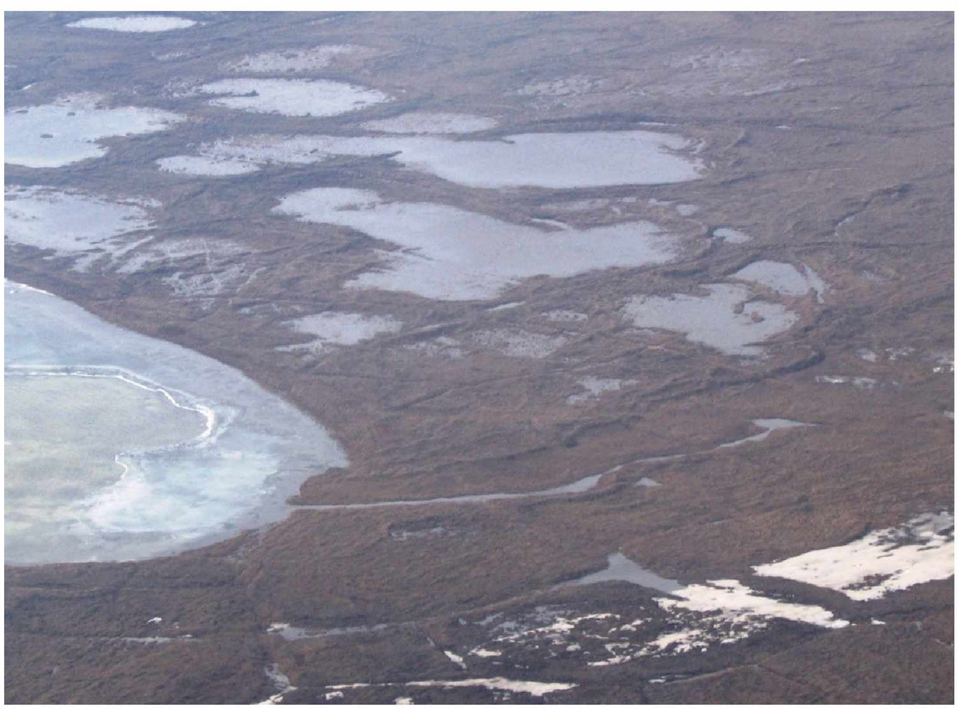


Lake M9922 Outlet June 3, 2008

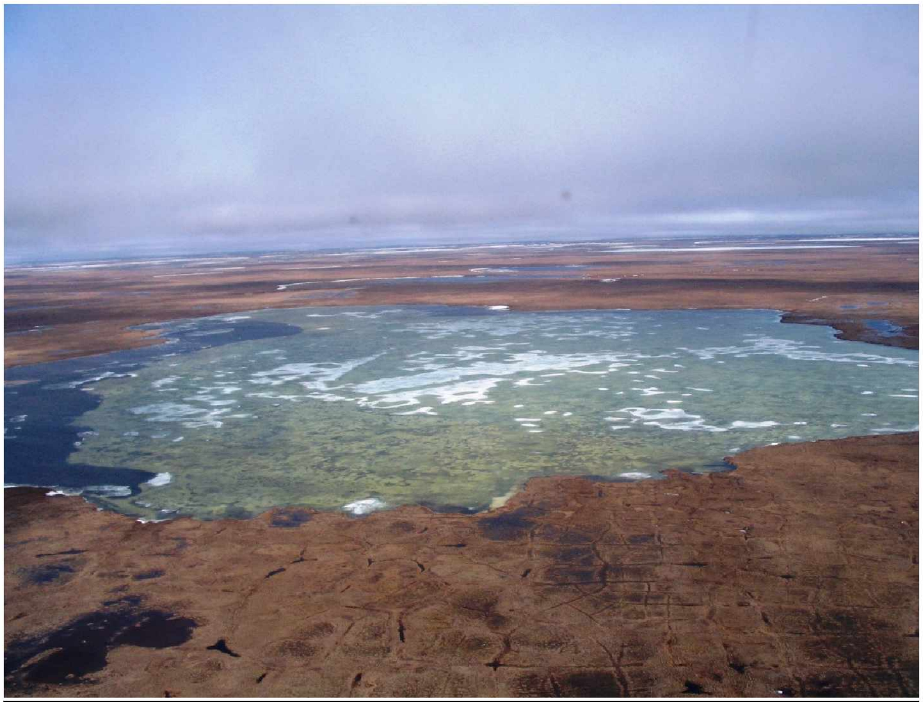
Lake L9923 June 3, 2008



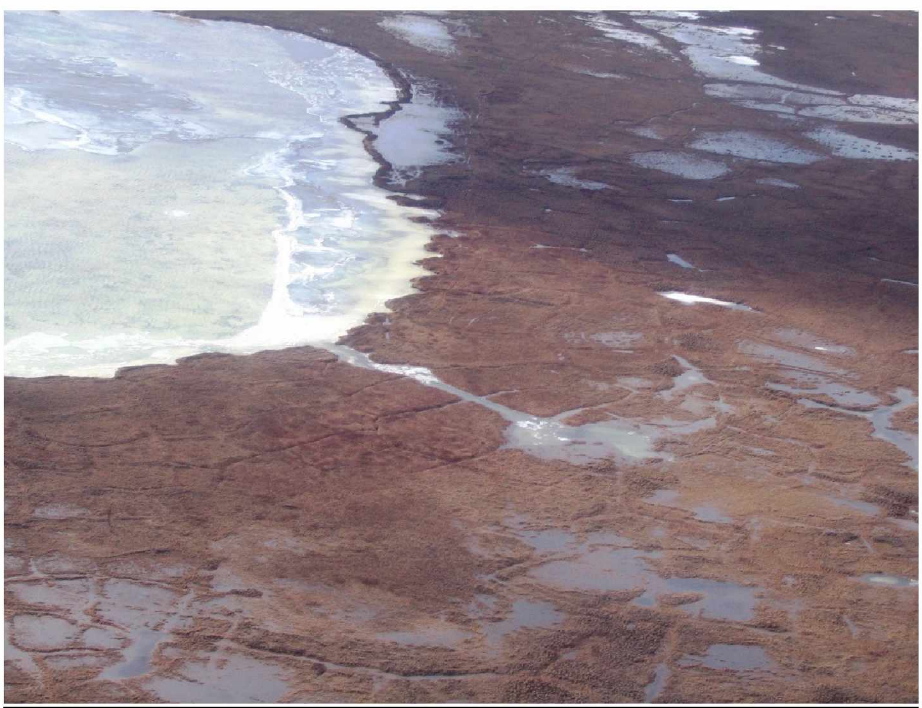
Lake L9223 Outlet June 3, 2008



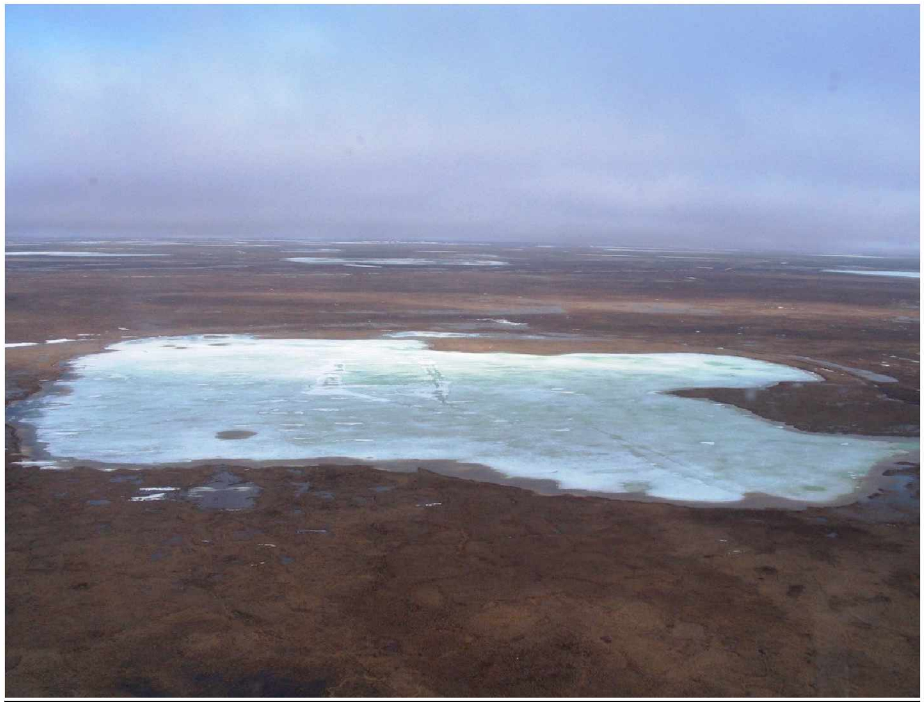
Lake L9225   June 3, 2008



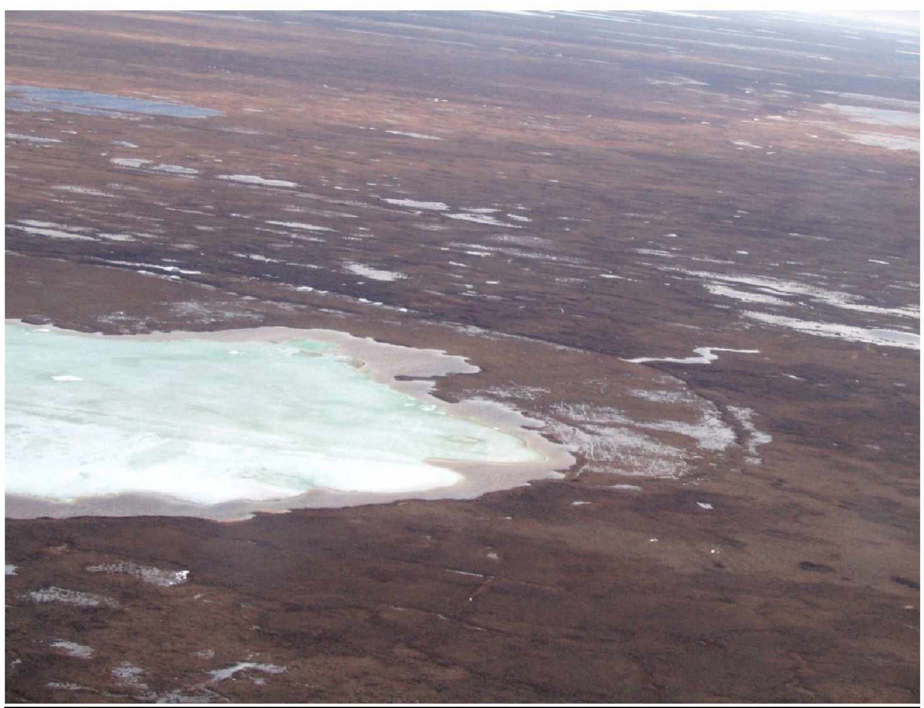
Lake L9225 Outlet   June 3, 2008



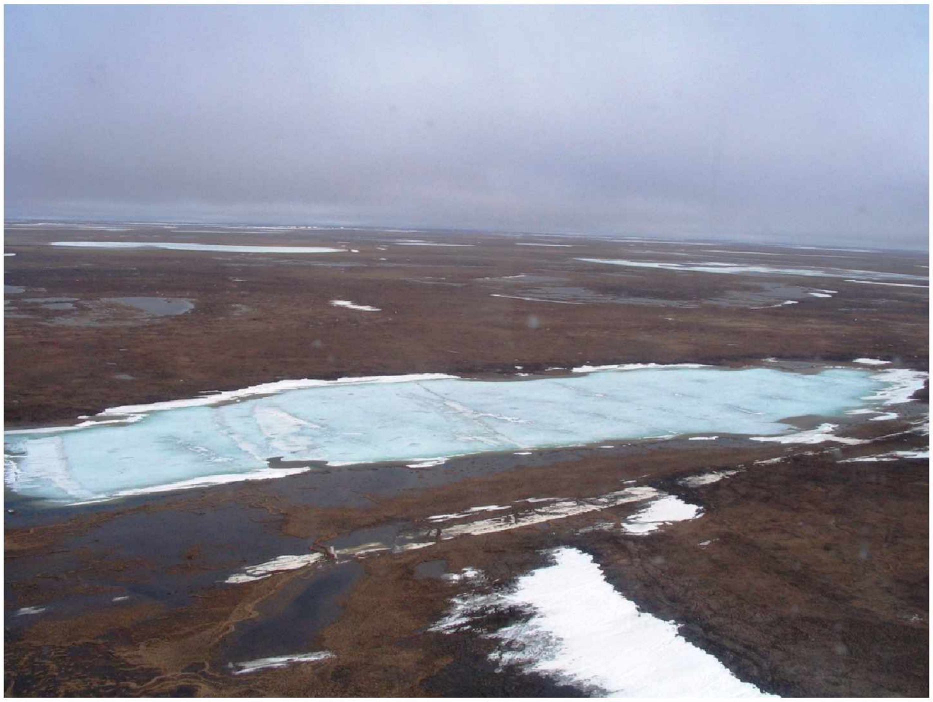
Lake Z06005 June 3, 2008



Lake Z06005 Outlet June 3, 2008



Lake Z06006 June 3, 2008



Lake Z06006 Outlet June 6, 2008